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Environmental Security Technology Certification Program – Project SI-0401 Final Report

Implementation and Commercialization of New Plant Germplasms for Use on Military Ranges

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Antonio J. Palazzo, Susan E. Hardy, and Timothy J. Cary

Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, New Hampshire 03755-1290

Kevin Jensen, Blair Waldron, and Steve Larson

United States Department of Agriculture
Agricultural Research Service
Logan, Utah 84322-6300

Final report

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Abstract: Our objectives were to demonstrate and make available new plant germplasms that are more beneficial for military training lands and to develop methods to better establish native plants that are competitive with invasive introduced plants. Under Strategic Environmental Research and Development Program (SERDP) project SI-1103, we developed germplasms that establish readily, stand up to wear from military vehicles, and compete well with invasive plants but are not themselves invasive. Validation and release of the new germplasms were accomplished under both the SERDP and Environmental Security Technology Certification Program (ESTCP) programs; under ESTCP we also initiated seed contracts and prepared a planting guide (Palazzo et al. 2009). Our ten releases (including six cultivars) are summarized in notices published in *Crop Science* or the *Journal of Plant Registrations*. One additional release is expected in the next year or two. Three germplasms were put into production, and the seed was made available for two years to land managers at eight Department of Defense (DoD) facilities. A commercial sale of 'FirstStrike' slender wheatgrass has been completed. We also developed seeding methods that have proven successful on eastern and western ranges to establish viable native plant stands quickly and compete with invasive plant establishment.

Contents

Figures and Tables

Figures

Tables

Preface

Funding for the project was supplied by the Environmental Security Technology Certification Program (ESTCP) under Project SI-0401. The Army Environmental Command (AEC) supported additional aspects of the research, both financially and technically.

This report was prepared by Antonio J. Palazzo, Susan E. Hardy, and Timothy J. Cary of the Biogeochemical Sciences Branch, U.S. Army Engineer Research and Development Center (ERDC), Cold Regions Research and Engineering Laboratory (CRREL), Hanover, New Hampshire, and by Dr. Kevin Jensen, Dr. Blair Waldron, and Dr. Steven Larson, United States Department of Agriculture (USDA)–Agricultural Research Service, Logan, Utah.

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The report was prepared under the general supervision of Dr. Terrence Sobecki, Chief, Biogeochemical Sciences Branch; Dr. Lance Hansen, Deputy Director; and Dr. Robert E. Davis, Director, CRREL. The Commander and Executive Director of ERDC was COL Gary E. Johnston. The Director was Dr. James R. Houston.

Terminology

Breeders, foundation, and certified seed. *Breeders* seed is produced from the last cycle of selection. This seed is used to produce *foundation* seed, which, in turn, is used to establish *certified* seed fields from which seed is produced for commercial sale.

Cultivar vs. germplasm. Plant materials developed in this project were released as "cultivars" or a level of pre-variety "germplasm." A *cultivar* (sometimes called a variety) is a population that is unique for selected traits and that has undergone multiple cycles of selection and extensive testing over multiple locations. A cycle refers to a complete generation from seed to plant (selection) to seed. Cultivars are genetically stable. A *germplasm* (pre-cultivar) can be a single genotype or a collection of multiple genotypes from multiple origins that are unique for a given character, but have not undergone nor met the more rigorous requirements for a cultivar. Germplasms may be released as one of three levels—source-identified, selected, or tested class—depending on the level of selection or testing.

Introduced vs. naturalized vs. native species. In this report, we use the term *introduced* to represent species not indigenous to North America. Many of the introduced plant materials on western rangelands, including those in this project, originated in Central Asia where they occur in very different ecosystems. The superior stand-establishment characteristics, hardiness, wide adaptability, persistence under grazing, availability and lower cost of seed, and productivity of introduced perennial species compared with indigenous *native* species have been documented in many regions (Barker et al. 1977; Vallentine 1977; Kilcher and Looman 1983; Lawrence and Ratzlaff 1989). Like their native counterparts, introduced grasses have the capacity to sort by natural selection and improve their adaptation to the environmental conditions on sites where they are seeded. As a result, many of the introduced species included in the project are *naturalized*, having existed in stands for over 50 years. These naturalized species have co-existed with native flora on North American rangeland (both private and public) for years. Within this report, we use only the terms introduced and native, based on the species origin.

Invasive. For the purposes of this study, we defined an *invasive* species as an introduced species that will spread beyond the areas it currently inhabits and prevent the establishment of desired perennial plants. We do not agree with definitions of invasive that equate it to any introduced or exotic species. Tiller and rhizome development and seedling encroachment through seed dispersal are potential indicators of invasiveness. Except for 'RoadCrest' crested wheatgrass, which is moderately rhizomatous and is best suited for cantonments and roadsides, we did not use any introduced species displaying these characteristics. On the other hand, rhizome development is valuable in desired native species for land stabilization and reclamation of disturbed lands. We worked with some rhizomatous natives to improve establishment and persistence of desired species.

Resiliency. We define *resilient* grasses as those better able to withstand training without being permanently damaged. This trait can be accomplished in two ways. Plants that *establish* more quickly will be larger and therefore more capable of withstanding training. Also, plants that can *recover* after being trained on (i.e., via rhizome spread) can adjust to changes in land use and maintain a vegetative sward.

Acronyms and Abbreviations

ACOM	U.S. Army Command (formerly Forces Command, FORSCOM)
AEC	Army Environmental Command
AFLP	Amplified Fragment Length Polymorphic
AOSCA	Association of Official Seed Certifying Agencies
ARS	Agricultural Research Service
ATTACC	Army Training and Testing Area Carrying Capacity
CERL	Construction Engineering and Research Laboratory
CRREL	Cold Regions Research and Engineering Laboratory
DoD	Department of Defense
ECAM	Environmental Cost Analysis Model
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ESTCP	Environmental Security Technology Certification Program
DPG	Dugway Proving Ground
FF	fine fescues
FORSCOM	Forces Command (Army); now ACOM
HG	hairgrass
INRMPs	Integrated Natural Resources Management Plans
ITAM	Integrated Training Area Management
LCTA	Land Condition Trend Analysis (now RTLA)
MRTFB	Major Range Test Facility Base
NGB	National Guard Bureau
NPA	Northern Plains Area Regional Trials
NRCS	Natural Resource Conservation Center
PVP	Plant Variety Protection
RAPD	Random Amplified Polymorphic DNA

ROD	Record of Decisions
RTLA	Range and Training Land Assessment (formerly LCTA)
SERDP	Strategic Environmental Research and Development Program
SI	sustainable infrastructure
SRP	Sustainable Range Program
SG	switchgrass
USDA	U.S. Department of Agriculture
WL	weeping lovegrass
WYARNG	Wyoming Army National Guard
YTC	Yakima Training Center

List of Plant Species Used in Project

Common name	Scientific name	Range relative to US
Alfalfa	*Medicago sativa*	Introduced
Basin wildrye	*Leymus cinereus* (Scribn. & Merr.) Á. Löve	Native (Western U.S.)
Beardless wildrye	*Leymus triticoides* (Buckley) Pilg.	Native (western U.S.)
Bering hairgrass	*Deschampsia beringénsis*	Native (northeastern and western US)
Big sagebrush	*Artemisia tridentata*	Native
Bluebunch wheatgrass	*Pseudoroegneria spicata* (Pursh) A. Löve	Native (western US)
Blue gramma	*Bouteloua gracillis*	Native (western US)
Buffalograss	*Bouteloua dactyloides* (Nutt.) J.T. Columbus	Native (midwestern US)
Cheatgrass	*Bromus tectorum* L.	Introduced invasive weed
Crested wheatgrass (Fairway type)	*Agropyron cristatum* (L.) Gaertn.	Introduced
Crested wheatgrass (Standard type)	*Agropyron desertorum* (Fisch. ex Link) Schult.	Introduced
Forage kochia	*Kochia prostrata* sp. virescens	Introduced shrub
Hard fescue	*Festuca brevipila* R. Tracey	Introduced
Kentucky bluegrass	*Poa pratensis L.*	Native (northern US)
Little bluestem	*Schizachyrium scoparium* (Michx.) Nash var. *scoparium*]	Native
Medusahead rye	*Taeniatherum asperum* (Simonk.) Nevski	Introduced invasive weed
Purple needlegrass	*Nassella pulchra* (Hitchc.) Barkworth	Native (California)
Russian wildrye	*Psathyrostachys juncea* (Fisch.) Nevski	Introduced
Sandberg bluegrass	*Poa secunda* J. Presl	Native (western US)
Sheep fescue	*Festuca ovina* L.	Introduced
Siberian crested wheatgrass	*Agropyron fragile* (Roth) P. Candargy	Introduced
Slender wheatgrass	*Elymus trachycaulus* (Link) Gould ex Shinners	Native
Snake River wheatgrass	*Elymus wawawaiensis* ined.	Native (northwestern US)
Switchgrass	*Panicum vergatum* L.	Native
Tall fescue	*Festuca arundinacea* Schreb.	Introduced
Thickspike wheatgrass	*Elymus lanceolatus* (Scribn. & J. G. Sm.) Gould	Native
Tufted hairgrass	*Deschampsia cespitosa* (L.) P. Beauv.	Native (northeastern and western US)
Weeping lovegrass	*Eragrostis curvula* (Schad.) Nees	Introduced
Western wheatgrass	*Pascopyrum smithii* (Rydb.) Á. Löve	Native (western US)
Western yarrow	*Achillea millefolium* L.	Native forb

1 Introduction

1.1 Background

The Department of Defense (DoD) must constantly balance its military mission and its commitment to stewardship as it operates millions of acres of ranges and training lands. The military mission requires that vegetation — primarily grasses — be as resilient to military training activities as possible to maintain realism and to control soil erosion.

The military faces increasingly difficult land-management challenges as weapons technology improves and training and testing needs change. Complicating this challenge is the impact of continuing development, especially urbanization, outside the boundaries of military installations. As populations grow and urban expansion continues, landscapes around facilities will be further degraded, and additional pressures will likely be brought to bear on native species, biological communities, and the ecological processes that sustain them. This growing pressure may intensify demands that federal land managers take on even greater responsibilities for biodiversity conservation (Keystone Center 1996).

When indigenous species are lost, undesirable or invasive annual species often grow in those same areas. Invasive annual plants are a problem on military lands because (1) they can reduce training realism, (2) they do not retard soil erosion as well as do perennial species because they leave the land barren during the winter months, (3) operations to detect and control them use valuable mission resources, and (4) they can take over and destroy the habitat for desirable or threatened and endangered species. The prevalent method for controlling invasive plants on military lands is herbicide application, but this option was reduced beginning in 2001. Research on pest or animal control of invasive plants is currently active in many public weed-control programs, but there is limited knowledge of the interrelationships of invasive and desirable plant species. To compete with the annual invasive or noxious weeds, sown species should germinate readily and have rapid growth rates soon thereafter.

Our goals have been both to develop plants more resilient to military training activities and to get native plants to establish more rapidly so that the land could more quickly be returned to military use. Through our

Strategic Environmental Research and Development Program (SERDP) project to "Identify resilient plant characteristics and develop a wear-resistant plant cultivar for use on military training lands" (Sustainable Infrastructure project SI-1103), we bred native and introduced grass and forb germplasms with improved establishment and seedling vigor. We also developed seeding methods to further enhance the ability of our modified germplasms to establish viable native plant stands as rapidly as possible. Our modified germplasms may be used over a broad area of the Intermountain West Region of the U.S., and our seeding methods have proven successful on eastern and western ranges (Fort Drum, New York; Yakima Training Center, Washington; and Fort Carson, Colorado). During the SERDP project (Palazzo et al. 2003), we began some large-scale demonstrations and held a workshop for federal, state, and regional land managers as well as representatives of seed companies (Hardy and Palazzo 2002). The goals of this ESTCP project were to further demonstrate and validate the germplasms and our seeding methods and to make the modified seeds available to land managers.

Before our efforts, there was little or no research on the genetics or resiliency of low-maintenance rangeland plants. In our plant-breeding research, we were able to improve traits related to establishment and resiliency to training activities in introduced and native species of rangeland grass plants, compared to existing, commercially available cultivars. We recognized, however, that even with their improved establishment rates, our new germplasms would not always be able to compete with the very aggressive establishment of annual invasive plants.

To find better ways to establish native plants, we developed the concept of "ecological bridges." In this innovative work, we investigated root growth and establishment relationships among various species and, from this knowledge, selected seed mixes of those rapidly establishing introduced grasses and desired native grasses. The species of introduced grasses selected varied with climatic and land-use conditions, but the primary criterion was for this plant to be relatively short-lived so that a native vegetative stand would develop. When properly selected, the introduced grasses will quickly protect the soil and create an environment in which the native grasses would gradually establish and dominate the seeded stand (Waldron et al. 2005). We also addressed the potential invasiveness of the germplasms we were developing by convening an independent review panel at Yakima Training Center in 1999 to evaluate the species,

especially the introduced ones, we were using in the breeding studies. The panel concluded that the plants were not encroaching into other plant communities and were not establishing monocultures (Palazzo et al. 1999).

1.2 Objectives of the demonstration

Our objective in this current ESTCP project was to bring the new germplasms and seeding methods to widespread use on DoD and other federal lands by demonstrating and further validating the new plant materials and seeding methodologies, investigating the release of cultivars, initiating seed contracts, and developing a planting guide for military facilities in the intermountain west. New plant materials are needed since many of the cultivars or germplasms of species purchased for use on military lands were originally developed for other uses such as for grazing. To accomplish this, we performed field evaluations and demonstrations of the new germplasms compared to existing cultivars of the same species and also compared seeding mixtures to standard military mixes. The comparative evaluations of the new germplasms enabled us to select germplasms suited for military lands. The technical differences of the new germplasms as compared to existing cultivars were documented through field or greenhouse evaluations.

The results of these comparisons were summarized in release notices published in either the journal *Crop Science* or the *Journal of Plant Registrations*. The release notices are a form of announcement that these plants have been developed and are available for production and distribution. The notices define the species and note how they are different from the more important cultivars or germplasms of the species currently on the commercial market.

The germplasms were released as either cultivars, selected class, or source-identified germplasms. Our aim was to bring as many germplasms as possible to full cultivar status, and we were successful for four species to date and potentially one more (two cultivars were released earlier during our SERDP project). In addition, those released as selected or source-identified germplasms remain desirable and should enjoy a market demand for the seed.

The comparative field evaluations of new germplasms with existing cultivars were conducted at Camp Guernsey, Wyoming; Fort Carson, Colorado; Yakima Training Center, Washington; and Dugway Proving

Ground (DPG), Utah. The demonstrations of ecological-bridge seed mixtures took place at Camp Guernsey, Wyoming; Yakima Training Center (YTC), Washington; and Fort Drum, New York. Additional cultivar evaluations were conducted at ERDC-CRREL and at various U.S. Department of Agriculture – Agricultural Research Service (USDA-ARS) nursery fields.

The only toxic compounds that might be used in demonstrations and evaluations, or in future applications of the products, are EPA-approved herbicides applied at the recommended rates. There are no waste stream emissions involved in the technology, nor, with the exception of the herbicide types and application rate, are there any applicable regulatory standards. Instead, the modified germplasms and establishment methods will reduce the overall need for herbicide applications in controlling noxious weeds at seeding time, and they will decrease the number of reseedings required in some situations. The technology will therefore allow training to occur again more rapidly, increase the diversity of species on the land, and reduce the likelihood of sediment or runoff from erosion.

1.3 Regulatory drivers

To be effective, the training mission must provide the resources for the military to meet their mission effectively. Military lands must be maintained in settings that provide the opportunity to practice individual and battle-focused tasks and missions in both realistic and challenging conditions. Throughout the DoD, land stewardship and management of its natural resources fall under the Sikes Act of 1960,[1] which promotes "effective planning, development, maintenance, and coordination of wildlife, fish, and game conservation and rehabilitation in military reservations on military lands." In Army Regulation AR200-1,[2] the Army military land stewardship integrates natural resources management objectives with land warfare training requirements. Environmental compliance requirements that address these issues include sections: 2.1.b "...Range and Road Maintenance" and 2.5.e "Sustainable Army Live-Fire Range Design and Maintenance." The management of lands is funded and

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[1] Sikes Act (16 USC 670a-670o, 74 Stat. 1052), as amended, Public Law 86-797, approved September 15, 1960. Available at: http://www.fws.gov/laws/lawsdigest/SIKES.HTML

[2] Army Regulation 200–1. Environmental quality, Environmental Protection and Enhancement. Headquarters, Department of the Army, Washington, DC. 13 December 2007. Available at: http://www.apd.army.mil/pdffiles/r200_1.pdf

prioritized through the Integrated Natural Resources Management Plans (INRMPs) process used at every military facility.

Our research objectives addressed these adversities by developing plant materials and seeding methods to help installations be good stewards of land resources while supporting the Sikes Act and its provisions for no net loss of training land.

2 Technology

2.1 Technology description

Prior to this demonstration, we conducted basic and applied research to develop the technology. We researched modified plant materials as well as methods of establishing and maintaining native plant stands on military lands through two consecutive Corps of Engineers basic research projects on determining the genetic diversity of native plants, a SERDP project (SI-1103) on breeding the new germplasms, and leveraged funding from the Army Forces Command (FORSCOM), Army Environmental Command (AEC), and the Wyoming National Guard Bureau (NGB) to implement our evaluations. With this funding, we made significant advances in using molecular markers to identify species and genetic diversity within species (Liu et al. 1997; Larson et al. 1999, 2000, 2001, 2003, 2006; Hu et al. 2000, 2001, 2005).

For genetic diversity, we now have the tools to assess the genetic differences and similarities in commercial and natural seed sources. These studies provided us with background knowledge of the state of genetic diversity and plant characteristics of native plants existing on military training lands. A natural extension of this earlier research was our desire to use that knowledge as a baseline to modify plant materials to improve low-maintenance, training-resilient, native vegetation on military lands without causing significant changes in genetic diversity on those lands.

We used traditional plant-breeding practices to develop modified germplasms (Figure 1). We surveyed representative DoD installations to identify the most promising species along with the characteristics in those species associated with resiliency to training activities. We collected native plants with the desired traits from training lands and other conservation lands, and we used the best lines of introduced species already assembled in nurseries at USDA-ARS and Pennsylvania State University. From nurseries and seeded evaluation trials from 1995 through 1998, we selected the most promising species to carry forward in the breeding program. In our program, breeding populations were typically subjected to two cycles of selection for traits such as stand-establishment vigor, rate of tillering and rhizome development, vegetative vigor, and seed-yield potential.

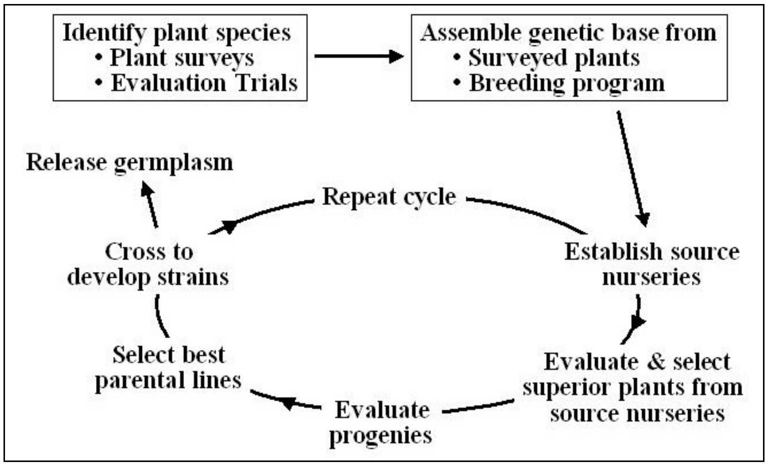

Figure 1. Plant-breeding cycle.

Although the main emphasis of the breeding program was on improving native species, introduced species were included early in the program. To ensure that the introduced germplasms we developed would not dominate lands currently inhabited by native species or prevent the return of native plants in the future, we convened an Independent Review Panel in May 1999 to evaluate the introduced species we were using in the breeding program. After evaluating 4- to 19-year-old plots at Yakima Training Center that had been seeded with the standard commercial cultivars of that time, the panel found that the species we were using were not encroaching into other plant communities and were not establishing monocultures (Palazzo et al. 1999). Although these plantings were too early to have included our modified germplasms, the panel found that the introduced species were filling in gaps but not spreading and pushing out native species, and thus were good candidates for our program.

We made four releases before the ESTCP project began (Asay et al. 1997, 1999; Jensen et al. 1998; Jones et al. 2002) and six more through the duration of the ESTCP project (Jensen et al. 2006, 2007, 2009; Waldron et al. 2006a, 2006b, in press). One additional release, a possible cultivar, is expected in the next year or two. Table 1 lists the current status and significant traits of each modified germplasm.

Table 1. Modified traits and current status of SERDP-select germplasms; (bold type indicates released germplasms).

Introduced selections	Original traits	Traits of modified populations	Release
Russian wildrye			
RWR-Tetra-1	Poor seedling vigor	Selected for improved seed germination and seedling vigor, increased plant height, longer and wider leaves, increased seedling emergence, heavier seeds, improved water-use efficiency	Jones et al. 1998 (source-identified)
Syn A		Improved seed germination. Part of parent population to develop Bozoisky-II	Not released;
'Bozoisky-II'		Selected for improved seed germination and seedling vigor	Jensen et al. 2006 (cultivar)
Crested wheatgrass			
'CD-II'	Moderate growth in cool temperatures;	Selected for increased growth under cold temperatures, drought resistance, easy establishment	Asay et al. 1997 (cultivar)
'RoadCrest'	Few rhizomes	Selected for low-maintenance turf with moderate rhizome development; suitable for gunnery ranges and roadside plantings; early spring growth	Asay et al. 1999 (cultivar)
Siberian wheatgrass **'Vavilov II'**	Moderate seedling vigor	Selected for seedling vigor, plant color, vegetative vigor, seed yield, drought tolerance, early spring green-up	Jensen et al. 2009 (cultivar)
Native selections	Original traits	Traits of modified populations	Release date
Bluebunch wheatgrass **P-7**	Hard to establish; sensitive to grazing	A broad-based multi-line population with no selection pressure applied	Jones et al. 2002 (selected-class)
Western wheatgrass 'Recovery'	Strongly rhizomatous	Selected for plant and seedling vigor, increased germination, seed yield	Waldron et al. in press (cultivar)
Snake River wheatgrass	Seedling vigor	Selected for increased seedling vigor and seed yield	*2011 (potential cultivar)*
Slender wheatgrass			
'FirstStrike'	Poor persistence	Broad-based bunch-type population selected for emergence from a deep planting depth; improved plant vigor	Jensen et al. 2007 (cultivar)
Rhizomatous population	Persistent	Selected for same as above plus rhizome development	dropped
Basin wildrye	Poor seedling vigor	Selected for improved seed germination and seedling vigor, increased plant height, longer and wider leaves, increased seedling emergence, heavier seeds, improved water-use efficiency	dropped
Sandberg bluegrass **Reliable**	Early establishment after a disturbance	A broad-based multi-line population with no selection pressure applied	Waldron et al. 2006a (selected-class)
Western yarrow (a forb) **Yakima**		A broad-based multi-line population with no selection pressure applied	Waldron et al. 2006b (source-identified class)

As part of our SERDP breeding project, we studied the use of non-invasive introduced grasses as an “ecological bridge” to the establishment of native grasses (Palazzo et al. 2003; Waldron et al. 2005) at Yakima Training Center, Washington; Fort Drum, New York; and Fort Carson, Colorado. We have promoted the concept at professional meetings and workshops with other federal and state agencies (Cary et al. 2001; Hardy and Palazzo 2002; Palazzo et al. 2001, 2002, 2006, 2007; Loffredo, et al., 2007). The concept has been well received and has gained interest with researchers and land managers. For example, the seeding mixtures we tested at Fort Drum now comprise the standard for that facility’s ranges (Palazzo et al. 1996, 2006, 2007; Hardy and Palazzo 2002).

The basic concept in the use of ecological bridge seedings is to select a geographically and climatically appropriate seed mixture of desired natives plus one or more rapidly establishing, introduced species that are not persistent. The introduced species provide an early protective vegetative cover to allow the natives to establish and eventually dominate the stand (Figure 2).

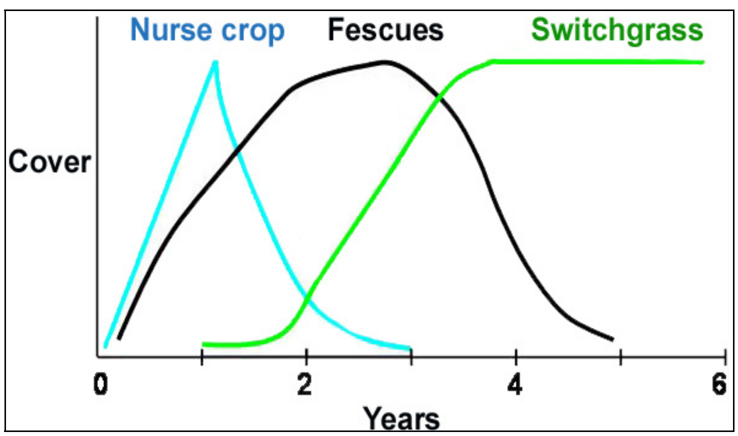

Figure 2. A conceptual model on how an introduced nurse-crop species acts as an “ecological bridge” on sandy soils at Fort Drum, allowing fescues and eventually the desired native grass, switchgrass, to become established.

In spring 2002, we held a 2-day workshop at Fort Carson and the Air Force Academy (Hardy and Palazzo 2002) to introduce land managers and seed companies to the modified germplasms and mixed seeding methods. The workshop was well received, and both users and commercial growers were interested in our new plant materials. Since this workshop, we have visited military facilities many times in the Intermountain West, presented posters or oral briefings at the Integrated Training Area Management (ITAM) or the Sustainable Range Program (SRP) meetings, and established

demonstration studies at four facilities to explain and show the benefits of the new germplasms.

Our new plant materials and seeding methods provide improved plant persistence on all military lands at a reduced environmental risk with respect to habitat loss and soil erosion. As native grass stands are established more quickly, military ranges will have decreased down times, offering reduced unit-training costs, increasing the value and use of current training areas, and enhancing DoD mission-related environmental activities.

No new equipment or skills are needed to use the new germplasms or seeding methods. "Implementation" of this technology requires the proper decision making for selecting appropriate revegetation materials. We have prepared a planting guide (Palazzo et al. 2009) that includes detailed information on plant selection for specific microclimatic ranges, training scenarios, and locations for optimal uses for each modified germplasm, as well as guidelines for selecting appropriate ecological bridge seed mixes.

2.2 Technology development

During the breeding process, candidate populations were tested at YTC, Fort Carson, and at breeding nurseries in Utah. Our final SERDP report (Palazzo et al. 2003) describes all of the evaluations performed during breeding and plant development. Related trials of many of the species modified in the breeding program are described by Asay et al. (2001) and Jensen et al. (2000). The ecological-bridge concept was tested at YTC, Fort Carson, and Fort Drum. This section presents the results of the breeding and ecological-bridge aspects of our earlier research.

2.2.1 Breeding resilient plants

The breeding program consisted of the following stages:

- **Assess:** We assembled a broad genetic base and selected the best accessions and clonal lines for desired characteristics.

- **Develop:** We made crosses among the best lines to produce progeny, conducted parent-progeny tests to initiate the second breeding cycle, and continued the breeding cycle as necessary.

- **Test and evaluate:** We tested new strains in replicated seeded trials and in soil compaction trials in the field. We also evaluated the new strains to ensure that they would not become invasive, and we analyzed the genetic diversity of the new strains.

In the **assessment** stage, we surveyed representative DoD installations to identify the most promising introduced and native species as well as the characteristics associated with resiliency in those species. Through research funded by Army FORCOM [now U.S. Army Command (ACOM)], we had already identified resilient plant species at several training sites using field surveys and the data generated by the ERDC-CERL Integrated Training Area Management (ITAM)–Land Condition Trend Analysis (LCTA) program [now the Range and Training Land Assessment (RTLA) program]. The LCTA program included monitoring of vegetation dominance on lands subjected to military training and provided information on the resiliency, persistence, and adaptation of plant species.

While making field collections, we identified plant characteristics that are critical to soil conservation, plant survival, and training resiliency. These traits included a vigorous ground cover; a deep, fibrous root system; tiller and rhizome development; initiation of growth early in the spring; persistence under environmental extremes (temperature and drought); and rapid establishment of seedling and plant. Table 2 shows the species used in the early assessment trials.

Table 2. Plant species used in pre-breeding trials.

Native Grasses			Introduced Grasses
Bluebunch wheatgrass	Thurber's needlegrass	Lovegrass	Crested wheatgrass
Snake River wheatgrass	Green needlegrass	Blue grama	Siberian wheatgrass
Wheatgrass hybrid	Idaho fescue	Side Oats grama	Intermediate wheatgrass
Western wheatgrass	Sheep fescue	Buffalograss	Russian wildrye
Slender wheatgrass	Sandberg bluegrass	Prairie Sandreed grass	Giant wildrye
Thickspike wheatgrass	Canby bluegrass	Little bluestem	
Bottlebrush squirreltail	Indian ricegrass	Sand dropseed	
Basin wildrye	Needle and thread grass	Galleta grass	
Native Forbs and Legumes			**Introduced Forbs, Legumes, and Shrubs**
Western yarrow	Spiny Hopsage		Forage kochia
Small burnett	Fourwing saltbrush		Cicer milk vetch
Bitterbrush	Globemallow		Alfalfa

To **assemble** the best lines for the introduced breeding populations, we looked for the desired characteristics among the plant materials already assembled in nurseries at USDA-ARS and Pennsylvania State University. To assemble the native breeding populations, we collected plants with the desired traits from training sites and other conservation lands.

We planted the assembled promising species in seeded evaluation trials at YTC and Fort Carson during the fall of 1994 and 1996. More than 60 cultivars, breeding lines, and plant accessions directly from the training sites were included in the YTC trials. Over 40 cultivars, breeding lines, and material indigenous to the training sites were included at Fort Carson. Visual percent stand and vigor ratings were taken throughout 1995, 1996, 1997, and 1998. From the nurseries and the seeded assessment trials, we selected the most promising species for the breeding process. Appendix Section D.1 contains data obtained during these initial pre-breeding evaluation trials.

In summary, the trials confirmed that introduced species established better than natives, with the natives usually taking 2–3 years to attain a stand greater than 50%. The findings suggest that adapted introduced grasses should be considered along with native grasses as a component of seed mixtures on environmentally harsh or degraded sites.

We used traditional **plant-breeding** techniques to combine desired traits into breeding populations. Figure 1 (above) shows a typical breeding program from plant surveys to germplasm release. Under normal conditions, it takes 2–3 years to complete one cycle of selection. The first year is a field-establishment year with no selection. The second and third years are for trait selection and seed harvest. If hybridization between selected clones is desired, it can take an additional year for isolation and seed increase for generation advance. With the exception of conducting plant surveys and assembling a broad genetic base (represented by the boxes at the top of Figure 1), the breeding cycle is repeated until the population has become genetically stable for the improved traits; each cycle increases the frequency of genes conditioning increased adaptation or specific traits. At some point after selection, the population is genetically stable from one generation to the next for the desired traits and may be released as a germplasm or, with more intense testing, as a cultivar.

In our program, we typically took plants through two cycles of selection. Most selections of parental lines where performed by analyzing measurable traits such as stand-establishment vigor, rate of tillering and rhizome development, vegetative vigor, and seed-yield potential. Native grasses with seed-dormancy problems were screened for more rapid germination. For future use, we used Random Amplified Polymorphic (RAPD) DNA or Amplified Fragment Length Polymorphic (AFLP) DNA analyses to identify genetic markers for desirable traits in some of the species. We also used both RAPD and AFLP DNA analyses to compare the genetic diversity of several new strains to their available counterparts.

Some new germplasms were not subjected to selection pressure. Instead, they were assembled from broad ecological ranges, resulting in a broader genetic base than in any of the individual populations and the subsequent potential to be better adapted to a wide range of different ecotypes.

Based on data from our field surveys and the seeded evaluation trials, we selected the three introduced and seven native species to carry forward in our breeding program to develop the new germplasms. The previously provided Table 1 lists those species and the current status of each.

Prior to formal release, cycle-2 breeding populations were established in seeded trials under a range of environmental conditions. Data obtained

from these trials were used to write up the formal release notices, which include areas of adaptation. Seed from cycle-2 populations—breeders seed—was also used to establish foundation seed-increase fields for those species that have been contracted for further seed increase and for commercial release as certified seed.

As noted earlier, we established an **Independent Review Panel** to assess whether the introduced species of interest are a threat to invade habitats other than those currently occupied by the species. For this review, we evaluated a site established 5 years earlier at YTC. We evaluated the species for spread (through either vegetative tillering or reseeding) after 4 years growth by counting plants growing outside the plots where they were planted. The Independent Review Panel met at YTC to view the sites and to discuss and make a definitive statement on the potential invasiveness of the plant materials. Although these plantings were too early to include our modified germplasms for those species, the panel found that the introduced species were filling in gaps but not spreading and pushing out native species, and thus were good candidates for our program.

2.2.2 Developing the ecological-bridge concept

The ecological-bridge concept was tested at YTC, Washington; Fort Carson; and Fort Drum.

At **YTC**, we tested the hypothesis that introduced Siberian wheatgrass could act as an ecological bridge to the establishment of the native bluebunch wheatgrass in a cheatgrass-infested area. The study was seeded on disturbed sites at Yakima Training Center in November 1998. We used Snake River wheatgrass (native), bluebunch wheatgrass (native), and Vavilov Siberian wheatgrass (introduced) planted in monocultures of each grass, planted in binary seed mixtures of Vavilov with each native grass, and planted in alternating rows of Vavilov with each native grass. Table 3 shows the percentage of cheatgrass in each plot in 2000, 2 years after establishment. Plots with Vavilov had lower amounts of cheatgrass. Significant reductions in cheatgrass occurred when Vavilov was planted in alternating rows with bluebunch or Snake River wheatgrass as compared with each of those natives planted without Vavilov. In the Vavilov and bluebunch combinations, Vavilov allowed bluebunch to get established (Palazzo et al. 2003).

Table 3. Percentage of cheatgrass in establishment-study plots at Yakima Training Center in 2000 (2 years after establishment).

	Row Spacing		
Grasses	25 cm	35 cm	Mean
Bluebunch wheatgrass	53	65	59
Snake River wheatgrass	35	78	57
Vavilov Siberian wheatgrass	7	30	19
Bluebunch/Snake River Mix	57	70	64
Bluebunch/Snake River Alternating Rows	30	52	41
Bluebunch/Vavilov Mix	17	47	32
Bluebunch/Vavilov Alternating Rows	30	52	41
Snake River/Vavilov Mix	25	48	36
Snake River/Vavilov Alternating Rows	25	48	36
Bluebunch/Snake River/Vavilov Mix	16	50	33
Mean	32	56	44
LSD (0.05)	23	19	15

At **Turkey Creek, Fort Carson**, we evaluated mixtures of native and introduced grasses in plantings (Waldron et al. 2005). Dormant-seeded in the fall of 1997, the treatments involved a core native-grass mix plus one of five additional introduced grasses. For comparison, the Fort Carson standard mix was also seeded at increased rates to match the above treatments. The plots were evaluated in 1999, 2000, and 2001 for species composition, percent ground cover, percent annual and biennial weeds, percent introduced grasses, and percent natives. After 3 years, all mixes resulted in stands with less than 5% weeds, but there was variation in how quickly weeds were suppressed and in how predominant the native species were in the stands after 3 years (Figure 3). The mixes with crested or Siberian wheatgrasses as the introduced species had the fewest weeds in all 3 years but resulted in the lowest establishment of native species. The mixtures with a Russian wildrye as the introduced grass had at least 60% natives from the first year on and resulted in the most diverse stands of natives, but the weeds were stronger in the first 2 years.

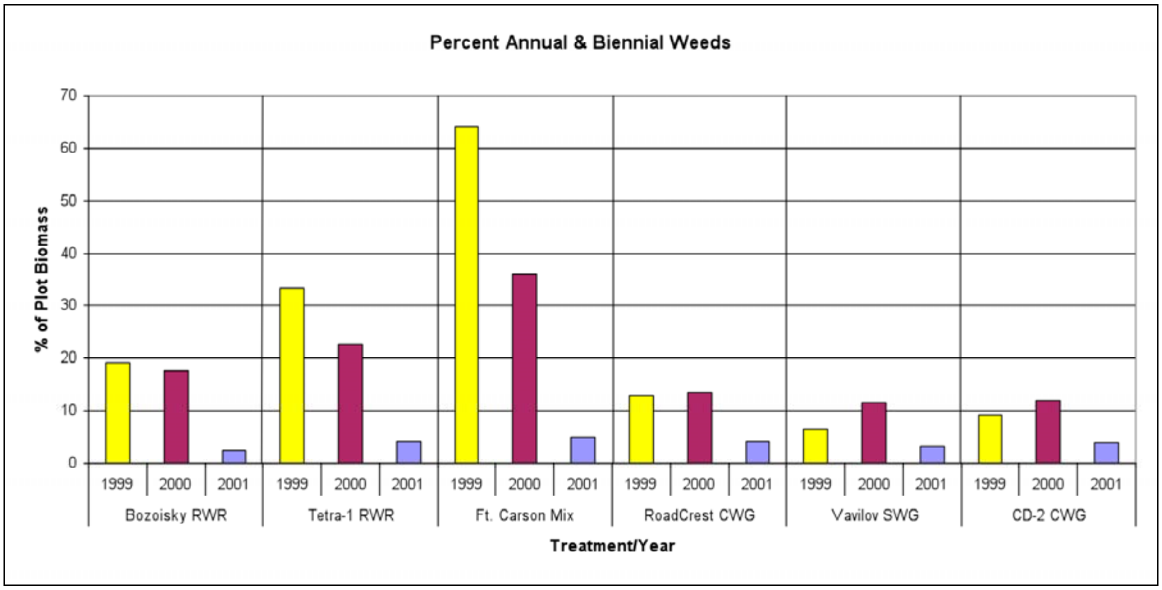

Figure 3. Percent annual and biennial weeds in Turkey Creek plots planted with the standard Fort Carson mix or with a core native mix plus an introduced grass (as named on the treatment axis).

The Fort Carson mix resulted in the greatest number of natives after 3 years, but the natives established more slowly, from about 30% to 90% over the 3 years, and the mix produced much less diversity among the natives species (Figure 4) (Palazzo et al. 2003; Waldron et al. 2005). These results suggest that there are several options, depending upon whether the main objective is rapid weed control on an area of frequent disturbance (core mix with crested wheatgrass) or the establishment of a diverse native stand in an area with fewer disturbances (military mix with western wheatgrass or, for greater erosion and weed control, core mix with Russian wildrye).

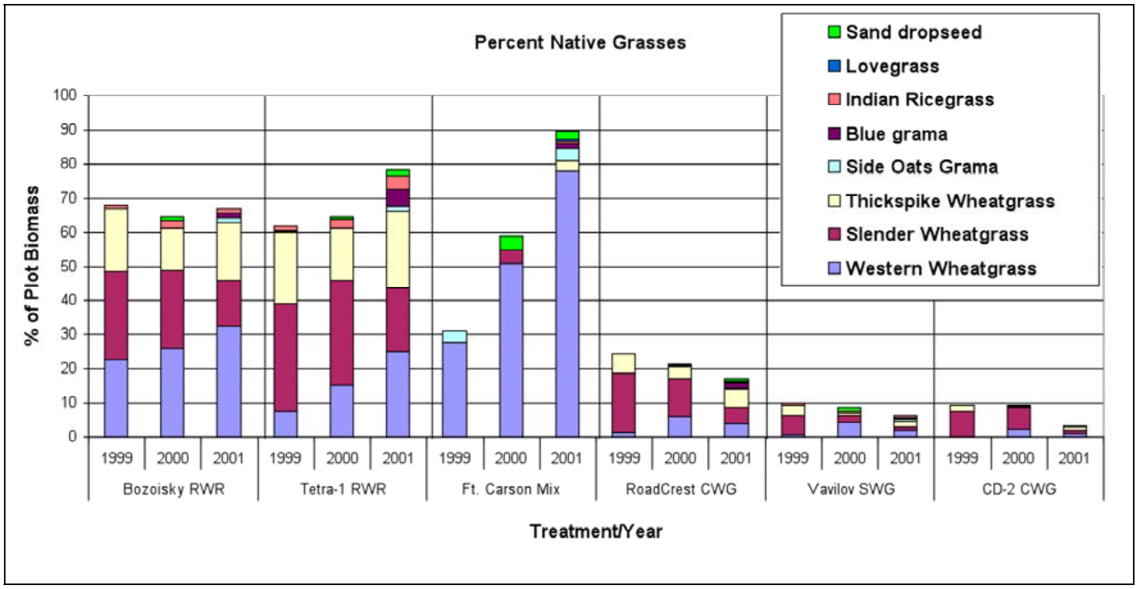

Figure 4. Percent native grasses in Turkey Creek plots planted with the standard Fort Carson mix or with a core native mix plus an introduced grass (as named on the treatment axis).

At **Fort Drum**, we planted mixed seedings of a nurse crop (weeping lovegrass) and fine fescues with the desired native switchgrass on difficult-to-revegetate sandy soils. Weeping lovegrass was not part of our earlier studies of introduced species, but we selected it for initial use as "nurse crop" at Fort Drum because, as a warm-season annual, we expected it to die out after the first season or two.

For treatments, we applied liquid cow manure at rates of 0, 22,400, 44,800, and 89,600 kg/ha (0, 10, 20, and 40 tons/acre). The manure slurry provided a mulching effect that prevented drying of the newly established plants, allowing time for them to develop roots long enough to reach into the deeper soil layers. All grass species appeared to grow better where the cow manure was applied, and good soil cover was obtained over the entire area in the initial season, through the strong growth of weeping lovegrass. The weeping lovegrass established quickly at all three rates sown, providing rapid control of wind and water erosion and allowing the land to be opened for training in about 1 year. The seeding provided a vegetative cover of greater than 85% in the first year with the manure applications, quickly protecting the soil and moisture. Establishment was not as good where manure was not applied, but it eventually established a good cover in the first year.

As a warm-climate annual, most of the lovegrass died back after the first or second year, allowing the fescues to come in. After 4 years, switchgrass dominated the stand (Figure 5).

Figure 5. Switchgrass dominating an ecological-bridge plot at Fort Drum, 4 years after seeding.

2.3 Advantages and limitations of the technology

With these new germplasms and seeding methods, land managers will be able to more quickly establish grass stands with improved resilience to training activities, and they will better be able to establish healthy native stands while relying less on chemical or mechanical means to control invasive plants (Palazzo et al. 2005). Ranges will therefore be less prone to erosion and be more available to training programs.

The only limitations to the technology beyond availability of the seeds, which this project has helped to overcome, are unusual drought or seasonal extremes, which would affect any plant materials. The modified germplasms have been selected to possess traits that maintain or improve upon a species' current ability to tolerate cool, dry conditions.

The "alternative" technologies that these modified seeds and methods will replace are the currently available seed sources and the current trial-and-error methods of selecting the best seed mixes.

3 Performance Objectives

Our primary performance objectives in this demonstration project were to evaluate the new germplasms developed under the SERDP program and to demonstrate the benefits of the ecological-bridge seeding methods that came from that same program. The evaluation portion of the program allowed us to determine the types of release suitable for the SERDP-select germplasms, to gather appropriate data for those releases, and to enhance our marketing efforts to seed producers and land managers. Table 4 below summarizes our performance objectives as stated in our Demonstration Plan along with the results for each objective. Detailed results are presented in Sections 5.6 and 6.

Table 4. Performance objectives.

Performance Objective	Metric (Expected Performance)	Data Requirements	Success Criteria	Results
Quantitative				
Improved establishment of SERDP-select germplasms compared to standard cultivars (Section 6.1)	Faster establishment rate for modified germplasms compared to standard cultivars	Stand establishment rates for SERDP-select germplasms and equivalent standard cultivars	Will have significantly ($P<0.05$) greater stand establishment than base population cultivar after 1 year	Four cultivars—Bozoisky-II Russian wildrye, FirstStrike slender wheatgrass, Recovery western wheatgrass, and Vavilov II Siberian wheatgrass—had significantly ($P<0.05$) greater stand establishment than base population cultivar after 1 or more years
Release new modified germplasms (Section 6.2)	Prepare and publish six germplasm releases describing new germplasms	Determine physiological characteristics of SERDP-select germplasms	Acceptance by AOSCA (2003) or equivalent state review board for certification within appropriate class germplasm	Four cultivars and two pre-variety germplasms have been released (see Table 1)
Release new modified cultivars (Section 6.3)	Satisfy criteria for release of two or more germplasms as cultivars	Conduct evaluations to compare establishment, persistence, rhizome development, etc., differences between SERDP-select and standard cultivars.	Satisfy necessary criteria for application to USDA as a PVP cultivar (actual acceptance can take 5–7 years after application)	Four cultivars have been released under ESTCP: Vavilov II Siberian wheatgrass, FirstStrike slender wheatgrass, Recovery western wheatgrass, and Bozoisky II Russian wildrye. We have the potential for one more cultivar release (see Table 1)
Improved resilience of grasses to military traffic (Section 6.4)	Increased resiliency of new germplasms to military traffic compared to varieties currently in use	1. Conduct tracking experiments on established stands 2. Evaluate plant stands after 1 year.	Significantly ($P<0.05$) better stands in new germplasms 1 year after tracking as compared to standard varieties	Three new cultivars—Bozoisky II Russian wildrye, Vavilov II Siberian wheatgrass, and SERDP-select Snake River wheatgrass—did significantly better than the commonly available varieties for all treatments.
Improved establishment of native grass stands (Section 6.5)	Greater establishment of natives in ecological-bridge seedings compared to standard mixes	Evaluate mixed seedings on at least two different sites.	Obtain a grass stand of native plants 4 years after planting	Accomplished at Fort Drum; all mixes at Guernsey established more rapidly and persisted better than the standard Guernsey mix (drought prevented evaluation for 4 years)

Performance Objective	Metric (Expected Performance)	Data Requirements	Success Criteria	Results
Reduce weeds in grasses on training lands (Section 6.6)	Reduced stands of noxious weeds in ecological-bridge seeding mixes compared to mixes currently in use or natives sown alone	Evaluate percentage of weeds in stands sown with ecological-bridge mixes, standard mixes, and natives sown alone	Significant ($P<0.05$) reduction of weeds in ecological-bridge stands as compared to natives sown alone after 2 years	No significant differences at YTC or Guernsey, although the highest percent weeds were found with the all native mix 2 and core native mix 4 at the Guernsey River site after 2 years.
Qualitative (Section 6.7)				
Reliability	Ability to withstand environmental conditions as well as or better than existing cultivars	Observations and data evaluation during demonstration	Planting in several different climatic locations	We have successfully established our modified germplasms at four facilities in two climatic areas within the 4-year time frame of this demonstration.
Ease of Use	No additional personnel or equipment required	Experience during demonstrations	No increase in time or cost required for soil preparation and seeding	Most operations can be completed with a single tractor pass; no new methods or equipment are required.
Versatility	Comparable results at two or more test sites	Evaluations of plant stands at two or more sites	Observation of improved performance at multiple sites	Modified germplasms were successful on different soils and climatic areas.
Maintenance	No need to reseed, fertilize, or mow	Evaluations during 2–3 years after planting	Experience during demonstrations	Plants required no maintenance after seeding; plant stands continued to thrive throughout the demonstration.
Scale-up Constraints	1. Availability of seed	a. Prepare breeders seed b. Contract with seed producers	Seed available from seed producers	a. Seed of three grasses was distributed to eight military facilities in the Intermountain West over 2 years. b. We have established one commercial seed contract
	2. Awareness of seed capabilities and appropriate planting methods	a. Prepare releases b. Prepare planting guide	Publish releases and planting guide; widely distribute planting guide	a. Six new releases have been published under ESTCP b. The Planting Guide has been published.

4 Site Description

The criteria for selecting our locations were their importance to the military mission and the degree to which their climates represent other DoD installations. We considered test sites in two climatic areas: the Intermountain West and the Northeast for the ecological bridge studies, and in the Intermountain West for our plant development research (Figure 6). Sites in these climatic areas had a diversity of landscapes in terms of soil thickness, microclimates, and terrain to support the need for multiple germplasm species grown in mixtures. The Intermountain West test sites also contain a diversity of microclimatic areas that contain a greater diversity of plant species than a single location. We also wanted to demonstrate the germplasms and seed mixtures on military lands that could potentially be subjected to military vehicle traffic as part of the validation testing. Yakima Training Center (YTC), Yakima, Washington; Fort Drum, New York; Camp Guernsey, Guernsey, Wyoming; and Dugway Proving Ground, Dugway, Utah, met these criteria, and they provided strong financial and personnel support.

Figure 6. The general range of distribution for SERDP-select germplasms, showing locations of the main demonstration sites and other military facilities in the Intermountain West as they existed at the beginning of this study.

The **comparative field evaluations** of new germplasms with existing cultivars were conducted at Camp Guernsey, YTC, and Dugway Proving Ground. The **demonstrations of ecological-bridge seed mixtures** took place at Camp Guernsey, YTC and Fort Drum. Earlier studies on our developing germplasms and ecological-bridge mixtures were performed at Fort Carson; our work at Fort Carson provided the basis for our cost analyses.

In addition to the larger demonstration studies, we conducted **further tests for cultivar validation** at the ERDC-CRREL greenhouse and at several nursery-field sites (Table 8). These additional locations are described in Section 5.3.4.

4.1 Site location and history

Yakima Training Center (YTC) is an Army facility in south-central Washington (Figure 6). We had done revegetation at YTC before and during our SERDP breeding program, and we used YTC for the tracked vehicle studies under the SERDP project (Palazzo et al. 2005). The area we used in this demonstration was Exit 11, which is in the northwest corner of the facility and is typically used for training with tracked or wheeled vehicles.

Camp Guernsey is a 17,070-ha (42,180-acre) Wyoming Army National Guard (WYARNG) military training area in southeastern Wyoming along the North Platte River (Figure 6). Camp Guernsey is the primary training area for WYARNG, with heaviest use occurring during the summer months. Training exercises conducted at Camp Guernsey include firing small arms (individual and crew-served weapons), artillery, and mortar; tactical and administrative bivouacs; engineer training; and bridging and river-crossing operations. Emphasis is on training field artillery units; however, training facilities and ranges are available for infantry, engineer, aviation, maintenance, and medical units. Other common training exercises conducted at Camp Guernsey include map exercises, tactical exercises without troops, command post exercises, situational training, field training, live fire, and lanes training. We used two sites: the River site, southeast of the cantonment adjacent to the North Platte River, and the Tower site, north of the cantonment near the radar tower. These two sites are primarily used for training with tracked and wheeled vehicles.

Dugway Proving Ground (DPG) is located in the Great Salt Lake Desert, approximately 85 miles southwest of Salt Lake City, Utah, within the eastern Great Basin, specifically the Bonneville Basin (Figure 6). The DoD has designated the 398,542-ha (798,855-acre) DPG as a Major Range Test Facility Base (MRTFB) and the primary chemical and biological defense testing center under the Reliance Program. Testers here determine the reliability and survivability of all types of military equipment in chemical or biological environments. The primary mission of DPG is to plan, conduct, analyze, and report the results of exploratory, developmental, and production tests of chemical and biological defense systems, and smoke and obscurant illumination material and delivery systems. The demonstration site was located at the highest elevation of the eastern part of the facility.

Fort Drum is located just east of Lake Ontario in upstate New York (Figure 6) and is under the command of the U.S. Army Commands (ACOM), formerly FORSCOM. The primary mission of Fort Drum is to provide facilities and services to U.S. Armed Forces that require land and airspace to practice combat skills and operations year-round. Fort Drum is also home to the 10^{th} Mountain Division (Light Infantry) whose mission is to deploy rapidly anywhere in the world and be prepared to fight and win upon arrival. The 10^{th} Mountain Division Light Infantry consists of light infantry brigades, an aviation brigade, a division artillery brigade, a division support command brigade, an engineer battalion, a signal battalion, an intelligence battalion, an air defense battalion, a military police battalion (provisional), a division band, and a headquarters company.

At Fort Drum, we used two study sites in the western part of the facility: training Area 8, about 5 miles north of the cantonment, and the Airport site, adjacent to the cantonment. The Airport site is a restricted area not used for training; Area 8 has been used for defilades (deep trenches).

Fort Carson is a U.S. Army Commands (ACOM) facility in south-central Colorado, south of Colorado Springs at 1,920 m (6,300 ft) elevation (Figure 6). The military mission of Fort Carson is to train, mobilize, deploy, and sustain combat-ready, multi-component integrated forces. Fort Carson provides facilities and service to U.S. Armed Forces that require land and airspace to practice combat skills and operations on a year-round basis. In our SERDP breeding program, we used the Turkey

Creek area near the northwest corner of the facility (38° 37' 20" N, 104° 52' 40" W). Our fenced study site was tilled to a depth of 20 cm (7.9 in.) to imitate disturbance and reduce existing weeds in spring 1997. Areas near the study site are regularly seeded with the military seed mix after disturbance by tracked vehicles during training exercises. We compared data from this study along with existing costs at Fort Carson to develop our cost savings information (see Section 7).

4.2 Site characteristics

Yakima Training Center encompasses an area over 130,000 ha (321,237 acres) in the Columbia basin of south-central Washington. The YTC region is part of the shrub-steppe, the largest of the grassland regions in North America (Rogers and Rickard 1998). YTC soils are typically loess overlying basalt, and the climate is characterized as semiarid, temperate, and continental with cold, wet winters and hot, dry summers (Jones and Bagley 1997). The region receives less than 25 cm (10 in.) of average annual precipitation. However, altitude plays a major role in site-specific annual precipitation. YTC sites about 455 m (1500 ft) altitude receive about 20.3 cm (8 in.), while sites near 910 m (3000 ft) altitude have lower temperatures and receive 30.5 cm (12 in.).

The YTC soils and vegetation are typical for central Washington state: shrub-steppe consisting of deep, silty, clay-loam soils (Drysel, Meloza-Roza; fine, montmorillonitic, mesic Xeric Camborthids) on a 0–3% slope; and dominated by big sagebrush (*Artemisia tridentata*) (Daubenmire 1970; Jones and Bagley 1997). The dominant vegetation is perennial bunchgrass such as bluebunch wheatgrass (*Elytrigia spicata*) or *Poa secunda*.

The climate at **Camp Guernsey** is considered semiarid with a total annual precipitation of 33–35 cm (13 in.). Peak precipitation occurs during May and June. Average daily temperatures range from –1 °C in the winter to 21 °C in the summer. The soils can be broken up into three areas: cantonment, north training area, and south training area. Soils in the south training area are shallow to moderately deep loamy and sandy with many areas of rock outcrops; slopes are moderately steep to steep. In the north training area soils are deep to moderately deep silty and loamy with gentle to moderately steep rolling hills (Warren et al. 2000). Our two sites are high plains, moderate relief rangeland. The River site is in the south training area near the North Platte River (N 42° 15.001' W 104° 44.090';

elevation 1320m [4330 ft]) and has very dry, sandy soil. The Tower site is in the north training area near the Guernsey Radar Tower (N 42° 14.385' W 104° 44.302'; elevation 1393 m [4570 ft]) and has silty soil. These two sites are representative of the warm- and cool-season grass transition zone where western wheatgrass is often a dominant species.

Surrounded on three sides by mountain ranges, the **Dugway Proving Ground**'s terrain varies from level salt flats to scattered sand dunes and rugged mountains. DPG is in the Great Salt Lake Basin where there is a great variability in precipitation patterns. On average, the area receives 19 cm (7.5 in.) of annual precipitation, but the lowest and highest amounts were 8.5 cm (3.32 in.) in 1966 and 38 cm (14.99 in.) in 1982. The average daily temperatures range from –2.5 °C in winter to 24.3 °C in summer, but it can reach 40 °C. The aridity of the area is caused by the rain shadows cast by the High Sierra Mountains of California and Nevada, and to a lesser extent by the Deep Creek, Pilot, and Snake Ranges of western Utah and eastern Nevada. The demonstration site was north of English Village where the soils are a fine sand, with 2–15% slopes. The main topographic features of DPG area are rugged, fault block mountains, generally running from north to south, with fairly level, intervening valleys. The Cedar Mountains, which are an example of this type of mountain range, form the northeastern boundary of the installation, terminating just north of English Village. The peak elevation of the Cedar Mountains is 2,340 m (7,700 ft), which is outside of the DPG boundary. (U. S. Army 2005.)

Fort Drum encompasses two major physiographic provinces, the Lake Erie-Ontario Lowlands and the Adirondack Uplands. The southwestern two-thirds of the installation, where the Airport and Area 8 sites are located, are part of the Lake Erie-Ontario Lowlands division. In this area, surface geological features are recessional moraines, small sand plains, drumlins, swamps, and drainage patterns resulting from Pleistocene glaciation. The geology at Fort Drum is underlain by a variety of metamorphic, igneous, and sedimentary bedrock ranging from Precambrian to Middle Ordovician. The oldest metamorphic rocks belong to the Grenville Complex and consist mainly of metamorphosed Precambrian quartzite, gneiss, schist, and marble. These rocks stretch in a wide northeast–southwest band across Fort Drum and border the igneous Adirondack massif and associated foothills to the east.

Fort Drum soils are generally developed from deltaic/lacustrine or glacial deposits. The soils vary from sandy gravels to loams to clays to mucks. Soils in the region are generally shallow and poorly drained; soil permeability is slow to moderate. The two study sites at Fort Drum are located on a Plainfield sandy soil and contained a mean of 92% sand, with small amounts of silt and clay. Both sites are on relatively level open areas with less than 25% tree canopy, and the areas were wind blown and mostly devoid of vegetation at the beginning of the study. Grasslands and meadows on sandy soils at Fort Drum are dominated by common hairgrass, stiff-leaved aster, poverty oat grass, and the sedge *Carex lucorum*. Grasslands on sandy soils are visually distinct from corresponding communities on less sandy soils, showing a relatively species-poor vegetative diversity with a predominance of native species.

Fort Drum has a primarily humid, continental climate with relatively long, cold winters and short, warm and often humid summers. The mean annual temperature, averaged over the past 10 years, is 8.9 °C (48 °F). January is the coldest month, closely followed by February and December. Temperatures fall below –18 °C (0 °F) on about 20 days during these 3 months; below-freezing temperatures occur on about 104 days from December to March. (U.S. Army 2001)

The **Fort Carson** research site at the Turkey Creek Recreation Area has soils that are a fine sandy loam (mixed, calcareous mesic Ustic Torriorhents). The 22-year mean annual precipitation for Colorado Springs is 38.3 cm (15 in.), with approximately 80% of this precipitation received from April to September. This site contains vegetation typical of the Great Plains steppe provinces (Bailey 1995). Shrubs are rare, but one-seed juniper (*Juniperus monosperma* [Engelm.] Sarg.) has encroached into grasslands during the last century. Dominant grass species include western wheatgrass, blue grama (*Bouteloua gracilis* [H.B.K.] Lag. ex Steudel), and sideoats grama *(B. curtipendula* [Michx.] Torr.). Subdominant grasses include green needlegrass [*Nassella viridula* (Trin.) Barkworth] and needle and thread grass (*Stipa comata* Trim & Rupr.).

5 Test Design

5.1 Conceptual test design

Demonstration activities included: (1) comparative field evaluations of new germplasms with existing cultivars, (2) evaluations of ecological-bridge mixes vs. standard mixes, (3) traffic tests on established plots, and (4) germination and nursery-field studies to further validate cultivars for release.

The comparative field evaluations of new germplasms with existing cultivars were conducted at Camp Guernsey, YTC, and DPG. The demonstrations of ecological-bridge seed mixtures took place at Camp Guernsey, YTC, and Fort Drum. Traffic studies on germplasms and mixes were conducted at YTC. Additional studies to validate germplasms for release were conducted at the ERDC-CRREL greenhouse and several USDA-ARS nursery-field sites.

At least six SERDP-select germplasms were tested at Guernsey, YTC, and DPG, along with a corresponding existing cultivar for each. The exact number of germplasms varied at each site, depending on seed availability and appropriateness to climate and soil conditions. In addition, two seed mixes were tested at one YTC location, and seven mixes were tested at two locations at Camp Guernsey. At Fort Drum, eight mixes were tested in two locations.

Three to four replicates were used for each seeding, with individual plots ranging in size from 18 to 36 m^2. Seeds were sown at a rate of approximately one seed per cm (2.5 seeds per linear inch). Plots at all sites were monitored yearly and measured for stand establishment or percentage of sown species, other plant species, weeds, and bare ground. Details of plantings and monitoring schedules are provided in the following sections.

5.2 Baseline characterization and preparation

The demonstration seeding sites at YTC and Camp Guernsey were in areas previously used for training. They were prepared by rototilling in the spring before planting, followed by summer applications of Roundup® for non-

selective removal of existing vegetation and Trimec® (2,4-dichlorophenoxyacetic acid [2,4-D]) for control of broad-leaf weeds; YTC sites received one spraying of the chemicals and Guernsey sites received three. Seeds were planted that fall at YTC (2002) and the following spring at Guernsey (2004 for the River site and 2005 for the Tower site) using a cone seeder equipped with double-disk furrow openers and depth band regulators (also called a no-till seeder).

At DPG we used disturbed bare land, so no preparation other than rototilling was needed. The site was tilled in the summer of 2005 and seeded that fall.

At Fort Drum, both research sites were relatively level and the areas were wind blown and devoid of vegetation at the beginning of both studies (May 2002). We first broadcast an application of 10-10-10 grade fertilizer at a rate of need of 0.72 t/ha (650 lb/acre). We next applied dolomitic limestone by broadcast at a rate of 0.91 t/ha (2,000 lb/acre). After application of soil amendments, the sites were divided into the respective study plots, and the seeds were sown with a Great Plains no-till seeder. The Area 8 site has previously been used for defilade training (trenches); the Airport site is in a restricted area not used for training.

No mobilization or installation was required at any facility other than travel of research personnel to the sites. There was no special equipment to be maintained, nor were there any hazardous wastes involved.

5.3 Design and layout of technology components

As noted above, demonstration activities included: (1) comparative field evaluations of new germplasms with existing cultivars, (2) evaluations of ecological-bridge mixes vs. standard mixes, (3) traffic tests on established plots, and (4) germination and nursery-field studies to further validate germplasms for release. These evaluations allowed us to confirm the types of releases suitable for the SERDP-select germplasms, gather appropriate data for those releases, and enhance our marketing efforts to seed producers and land managers.

Except as noted below, the demonstrations were similar at the selected sites. The setup details for each activity are given below; Section 5.4 gives the measurements taken at each site.

5.3.1 Field evaluations of new germplasms: comparisons of germplasms with existing cultivars (monocultures) — design

We seeded the monoculture evaluation plots at YTC, Camp Guernsey, and DPG to provide the required testing for release of any new cultivars and to demonstrate the potential superiority of the new germplasms compared to currently available cultivars. These studies provided data and a showcase for our marketing efforts, and allowed us to determine which SERDP-select germplasms would meet certification requirements for cultivars.

The Exit 11 site at YTC was seeded 21–22 October 2002. A second site (the River site) was seeded in spring 2004 at Camp Guernsey, and a third site (the Tower site) was seeded at Guernsey in Spring 2005. A site was seeded at DPG in fall 2005.

The trials were planted with a cone seeder equipped with double-disk furrow openers and depth band regulators. This seeder allows the comparison of entries with limited seed. Individual plots consisted of six drilled rows spaced 25 cm apart. Plot sizes were 1.5 x 24 m (5 x 80 ft) at YTC and 1.5 x 6 m (5 x 20 ft) at Guernsey and DPG. Seeds were placed 1.25–2.0 cm below the soil surface approximately 1 seed/cm (2.5 seeds per linear inch). Plots were arranged in randomized complete blocks with three or four replications at each site. The plants were not irrigated or fertilized; they were allowed to grow naturally in the local climate and soils. At YTC, the plots were subjected to military traffic after the plants are fully established (see Section 5.3.3 on military traffic).

The monoculture evaluations compared each of seven SERDP-select germplasms (four native and two introduced grasses plus one native forb, yarrow) with at least one standard cultivar. Additional species and varieties were planted in some locations; the lists below show only those of interest to this demonstration. (The native germplasms are given first, with the name of the standard cultivar used in all trials in parentheses.)

- Bluebunch wheatgrass, *Pseudoroegneria spicata* (Pursh) A. Löve (Goldar)
- Western wheatgrass, *Pascopyrum smithii* (Rydb.) Á. Löve (Rosana)
- Snake River wheatgrass, *Elymus wawawaiensis* J. Carlson & Barkworth (Secar)
- Slender wheatgrass, *Elymus trachycaulus* (Link) Gould ex Shinners (Pryor)

- Western yarrow, *Achillea millefolium* L. (commercial variety)
- Basin wildrye, *Leymus cinereus* (Trailhead)
- Sandberg bluegrass, *Poa secunda* (J. Presl), (common variety).

The introduced entries were as follows. The Syn A Russian wildrye line was developed prior to the initiation of the SERDP breeding program. Syn A was not released, but was used in the development of a subsequent cultivar, Bozoisky II, and is referred to as Bozoisky II parent in the summary tables in these sections. An additional Russian wildrye germplasm, Tetra 1 (Jensen et al. 1998), and two crested wheatgrasses, CD-II and RoadCrest (Asay et al. 1997, 1999), were released during the SERDP program and are used in many of the demonstration seedings (not listed below).

- Russian wildrye (Syn A), *Psathyrostachys juncea* [Fisch.] Nevski (Bozoisky-Select)
- Siberian wheatgrass, *Agropyron fragile* (Roth) Candargy (Vavilov)

Yakima Training Center, Exit 11. Monocultures and mixtures were seeded on 21–22 October 2002. Plots are 1.5 x 24 m (5 x 80 ft) with six rows at 25 cm (10 in.) apart. There were 9-m wide borders of Hycrest crested wheatgrass between replications. A detailed planting list by replications is given in Appendix Section D.2.

Camp Guernsey, River Site. Monocultures and mixtures were planted on 31 March 2004, with a plot size of 1.5 x 6 m (5 x 20 ft) with six rows at 25 cm (10 in.) apart. There were 1.5-m (5-ft) borders of CD-II crested wheatgrass between replications. A detailed planting list by replications is given in Appendix Section D.3.

Camp Guernsey, Tower Site. Monocultures and mixtures were planted 23 March 2005, with a plot size of 1.5 x 6 m (5 x 20 ft) with six rows at 25 cm (10 in.) apart. There were 1.5-m (5-ft) borders of CD-II crested wheatgrass between replications. A detailed planting list by replications is given in Appendix Section D.3.

Dugway Proving Ground. This site was seeded with monocultures on 7 November 2005 with a plot size of 1.5 x 6 m (5 ft by 20 ft) and a border of CD-II crested wheatgrass around the plots. A detailed planting list by replications is given in Appendix Section D.4.

5.3.2 Ecological-bridge demonstration (mixtures) — design

We evaluated mixtures at YTC, Camp Guernsey, and Fort Drum. Plots at YTC and Camp Guernsey were prepared and seeded with the monocultures as described above for germplasm evaluations in fall 2002 at YTC, and spring 2004 and 2005 at Camp Guernsey (see Sections 5.2 and 5.3.1). The two Fort Drum sites were prepared as described in Section 5.2 and seeded in 2002.

The same set of two mixtures was evaluated at both YTC and Guernsey. One set was an all-native mix and the second was an ecological-bridge mix containing both natives and selected introduced species (Table 5). At Camp Guernsey, an additional set of mixtures was evaluated (Table 6) with duplicate seedings at the two sites; these mixtures tested various ecological bridge combinations and compared them to the all-native mix in use at Camp Guernsey. The mixtures were planted as entries among the monoculture seedings at YTC and Camp Guernsey (see Appendix Sections D.2 and D.3 for planting lists by replication at each site).

Table 5. Seed mixtures planted at both YTC (Exit 11 sown in October 2002) and Camp Guernsey (River site, March 2004; Tower site, March 2005).

Mix 1: Introduced/native	Seeding rate (lb/acre)	Mix 2: All native	Seeding rate (lb/acre)
Western wheatgrass (SERDP)	4	Bluebunch wheatgrass (Goldar)	5
Russian wildrye (Bozoisky) (I)	3	Snake River wheatgrass (SERDP)	5
Siberian wheatgrass (SERDP) (I)	3	Western wheatgrass (SERDP)	5
Bluebunch wheatgrass (Goldar)	3	Western yarrow (SERDP)	0.1
Snake River wheatgrass (SERDP)	3	Sandberg bluegrass (common variety)	0.3
Western yarrow (SERDP)	0.1		
Forage kochia (I)	0.5		
Sandberg bluegrass (common variety)	0.3		

Table 6. Additional mixtures sown at Camp Guernsey in March 2004 (River site) and March 2005 (Tower site)

Mix	Native	% Seeds/ plot*	Introduced	% Seeds/ plot	Purpose / change
3. Current Guernsey mix	Little bluestem (Camper)	18	None		Current Guernsey mix for comparison with our proposed changes (4-7)
	Bluegramma (Lovington)	59			
	Buffalograss (Texoka)	4			
	Western wheatgrass (Rodan)	8			
	Thickspike wheatgrass (Critana)	11			
4. Test control	Bluegramma (Lovington)	24	None		Our suggested all-native control
	Western wheatgrass (SERDP TC2)	24			
	Thickspike wheatgrasses (Critana)	24			
	Slender wheatgrass (SERDP)	24			
	Buffalograss (Texoka)	4			
5. Test mix	Same natives as #4	#4 adjusted proportion-ally to 21.6 and 3.6%	Intermediate wheatgrass (AI)	10	Our suggested all-native mix plus single introduced species
6. Test mix	Same natives as #4	same as #5	Siberian wheatgrass (SERDP)	10	Test different introduced
7. Test mix	Same natives as #4	same as #5	Russian wildrye (SERDP Syn-A)	10	Test different introduced

* % seeds/plot = Percent pure live seeds (PLS) per plot, which is based on numbers of seeds, not seed weight; in spring 2004, 3600 seeds were planted in each 18-m^2 (100-ft^2) plot.

At **Fort Drum** we further evaluated the ecological-bridge concept with species adapted to the northeastern United States; we didn't test any of our modified cultivars. The Airport and Area 8 sites were sown in May 2002 to evaluate different seeding mixtures of the three ecological-bridge seed components. The research design was a two-way factorial; at least four to five samples were taken in each plot at each sampling time. No liquid cow manure was applied. Seeds were sown with a no-till seeder. The mixtures sown at each site are shown in Table 7. We varied the mixtures a bit from our earlier Fort Drum studies (see Section 2.2). While switchgrass is often desirable as a native, it grows tall and can carry fire, so we also tested native hairgrasses along with the shorter-growing introduced fescues. We were still using the annual weeping lovegrass as the nurse crop when these sites were seeded, although we have since dropped it as it could be considered invasive in some locations because it does not

completely die out over the winter months. The fine fescues were a blend of Azay sheep fescue and Scaldis and Osprey hard fescue, and the hairgrasses were a blend of Norcoast bearing hairgrass, Nortran tufted hairgrass, and a common variety of tufted hairgrass. The perennial grasses were sown in a mixture; the annual weeping lovegrass was sown separately; all seeds were sown at a depth of 1.5 cm.

Table 7. Mixtures seeded at two Fort Drum sites (22 May 2002).

Mixture	Species	Seeding rate (lb per Acre)
1	weeping lovegrass (WL)	2
2	weeping lovegrass	2
	hairgrass (HG)	38
3	weeping lovegrass	2
	switchgrass (SG)	38
4	weeping lovegrass	2
	hairgrass	38
	switchgrass	24
5	weeping lovegrass	2
	hairgrass	13
	switchgrass	12
	fine fescues (FF)	12
6	weeping lovegrass	2
	hairgrass	13
	fine fescues	24
7	weeping lovegrass,	2
	switchgrass	18
	fine fescues	18
8	weeping lovegrass	2
	fine fescues	38

Figure 7 and Figure 8 show the plot layout for the two Fort Drum sites; there was one replication or main plot at each site and no spaces between plots. The plots were sampled four times at random locations, and those samplings were used as replications to analyze the data. Plot sizes at the Airport site were oriented north to south and were 55 x 7.6 m (180 x 25 ft). At Area 8, plots were oriented northeast to southwest; each plot was 15.25 m (50 ft) wide; the plots varied in length from 30.5 m (100 ft) to 91.4 m (300 ft) to 121.9 (400 ft).

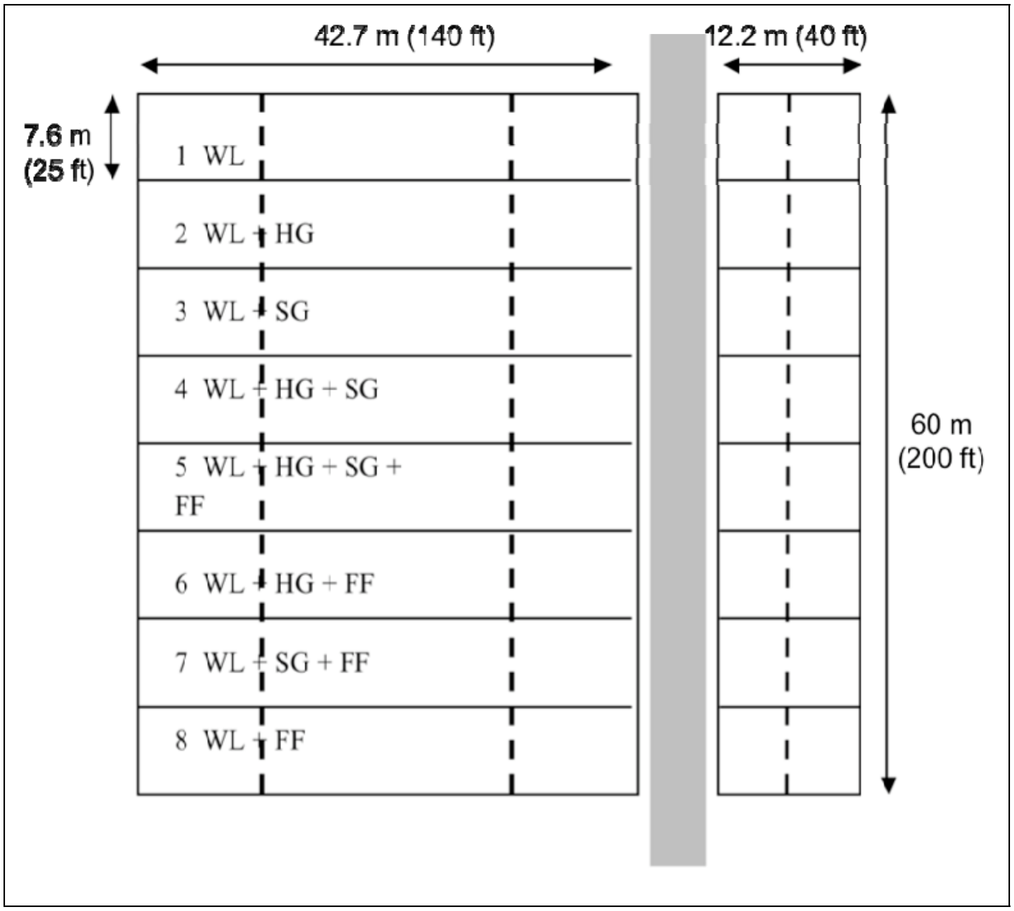

Figure 7. Arrangement of plots at the Fort Drum Airport site. WL = weeping lovegrass, HG = hairgrass, SG = switchgrass, FF = fine fescues (sheep and hard fescue).

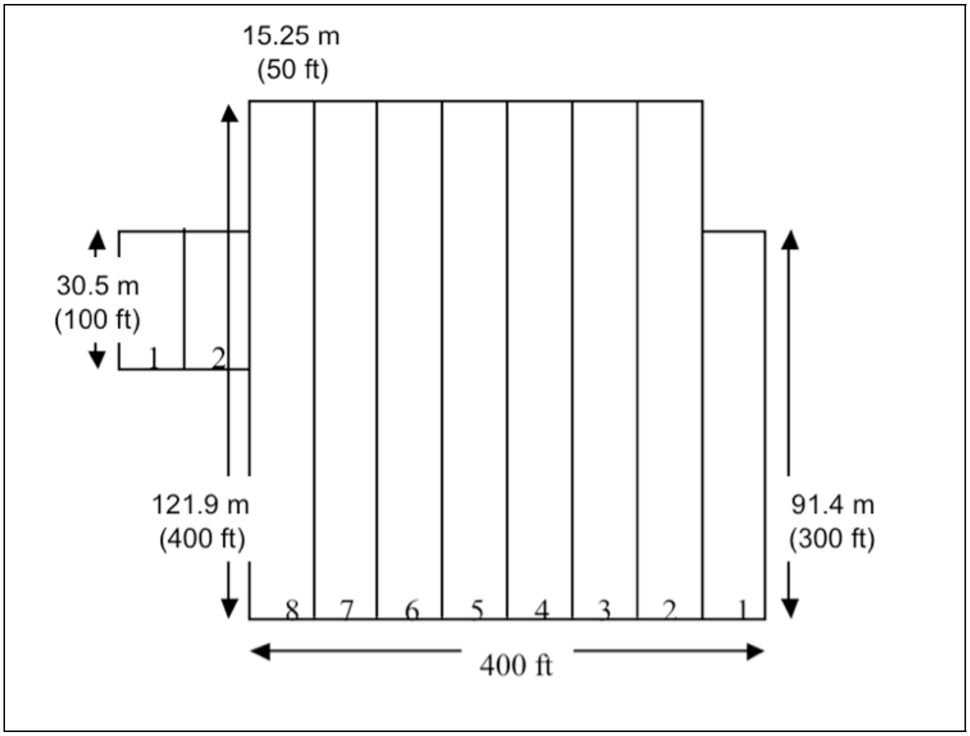

Figure 8. Arrangement of plots at the Fort Drum Area 8 site; the numbers represent the same mixtures as for the Airport site (Figure 7 and Table 7).

5.3.3 Military traffic on monocultures at Yakima Training Center — design

The objective of this evaluation was to compare the resiliency to military traffic of the SERDP-select germplasms that we developed with named cultivars currently on the market. Demonstration plots that were planted at YTC in October 2002 were subjected to military traffic in June 2005. A planned June 2006 tracking could not be carried out because a Stryker vehicle was not available. We monitored the plots for two seasons, completing the demonstrations by the fall of 2007.

As described above, the YTC Exit 11 plots were planted in October 2002 using a randomized complete block design with four replications and 20 species per replication. The cultivars of the species tested were the commercial variety as compared to the SERDP-select germplasm. The species tested (with named cultivars in parentheses) were: bluebunch wheatgrass (Goldar), Russian wildrye (Bozoisky-Select), Sandberg bluegrass (common), Siberian wheatgrass (Vavilov), slender wheatgrass (Pryor), Snake River wheatgrass (Secar), western wheatgrass (Rosana), Basin wildrye (Trailhead), and western yarrow (common). The tracking operations are described below in Section 5.4.

5.3.4 Cultivar validation: germination and nursery-field studies — design

Additional data needed to validate releases of the new germplasms were acquired through germination studies at CRREL and additional nursery-field trials. Appendix C summarizes the various types of pre-variety and cultivar releases and the requirements to meet each level of release.

Germination studies were conducted in April 2005. The SERDP-select germplasms were evaluated against their known counterparts in the CRREL environmental chambers located in the greenhouse. Ten seeds of each of the various plants were placed in growth pouches in growth chambers to study plant root initiation differences. There were five replications of each germplasm per run, with each temperature run four times for a total of 200 seeds studied. The environmental chambers were set at temperatures of 10, 15, 20, 25, and 30°C with 12 hours of daylight. Plant root initiation for the seed was determined according to the Association of Official Seed Certifying Agencies (AOSCA) publication (2003). Pouches were examined daily for up to 28 days.

Space-planted nursery-field trials to validate our cultivars as compared to other range grass cultivars were conducted at several USDA sites to provide data for Exhibits B, C, and D for Plant Variety Protection (PVP) as described in Appendix C. Six nursery-field trials for Bozoisky II Russian wildrye were planted in 1999 during our SERDP project as part of the Northern Plains Area Regional Trials (NPA). Between 2002 and 2005, five fall-dormant-seeded nurseries were established to compare seedling establishment and stand development of our other cultivars (Recovery western wheatgrass, FirstStrike slender wheatgrass, Vavilov II Siberian wheatgrass) and other range grass cultivars. Data from the YTC Exit 11 (fall-dormant-seeded), the two Camp Guernsey sites (spring-seeded), and Dugway (fall-dormant-seeded) were also included in cultivar validation. Plots in each trial were arranged in a randomized complete block with four replications. Entries were seeded at a rate of one pure live seed cm^{-1} at a seeding depth of 0.63 cm in five rows. Plots size was 1.5 x 8 m. Table 8 lists the nursery-field sites and ecoregions they represent.[3]

[3] Level III and Level IV Ecoregions of the Continental United States, National Health and Environmental Effects Research Laboratory, U.S. EPA

Table 8. Locations of space-planted nursery-field trials for cultivar validation

Site	Location	Annual precip.	Ecoregions	Cultivar validation data for
Beaver, UT	38° 20' N, 112° 35' W; elevation 1979 m;	34.3 cm	Level III Central Basin and Range, Level IV Woodland- and Shrub-covered Low Mountains	Recovery western wg
Malta, ID	42° 18' N, 113° 11' W; elevation 1480 m;	27.9 cm	Level III Northern Basin and Range, Level IV Saltbush Dominated Valleys	Recovery western wg FirstStrike slender wg Vavilov II Siberian wg
Fillmore, UT site 1 (lower site)	39° 12' N, 112° 14' W; elevation 1776 m	37.6 cm	Level III Central Basin and Range, Level IV Sagebrush Basins and Slopes	Recovery western wg FirstStrike slender wg
Fillmore, UT site 2 (upper site)	39° 13' N, 112° 12' W; elevation 1843 m	39.5 cm	Level III Central Basin and Range, Level IV Woodland- and Shrub-covered Low Mountains	Recovery western wg FirstStrike slender wg Vavilov II Siberian wg
Curlew Valley, ID	42° 02' N, 112° 40' W; elevation 1405 m	30.7 cm	Level III Central Basin and Range, Level IV Shadscale-dominated Saline Basins	Recovery western wg Vavilov II Siberian wg Bozoisky II Russian wr
Exit 11, Yakima, WA	46° 50' N, 120° 22' W; elevation 700 m	22.6 cm	Level III Columbia Plateau, Level IV Yakima Folds	Recovery western wg FirstStrike slender wg Vavilov II Siberian wg Bozoisky II Russian wr
River site, Camp Guernsey, WY	42° 15' N, 104° 44' W; elevation 1320 m	31.7 cm	Level III High Plains, Level IV Moderate Relief Rangeland	Recovery western wg FirstStrike slender wg Vavilov II Siberian wg Bozoisky II Russian wr
Tower site, Camp Guernsey, WY	42° 14' N, 104° 44' W; elevation 1393 m	31.7 cm	Level III High Plains, Level IV Moderate Relief Rangeland	Recovery western wg FirstStrike slender wg Vavilov II Siberian wg
Dugway, UT		19.5 cm	Level III Central Basin and Range, Level IV Woodland- and Shrub-covered Low Mountains	Vavilov II Siberian wg
Bluecreek, UT	41° 56' N, 112° 26' W, elevation 1653 m	35.0 cm	Level III Central Basin and Range, Level IV Sagebrush Basins and Slopes	Bozoisky-II Russian wr

Site	Location	Annual precip.	Ecoregions	Cultivar validation data for
Green Canyon, UT	41° 46' N, 111° 47' W, elevation 1520 m	44.9 cm	Level III Central Basin and Range, Level IV Malad and Cache Valleys	Bozoisky-II Russian wr
Mead, NE	41° 13' N, 96° 29' W	70.6 cm	Level III Western Corn Belt Plains, Level IV Nebraska/Kansas Loess Hills	Bozoisky-II Russian wr
Sidney, NE	41° 23' N, 103° 0' W	42.2 cm	Level III High Plains, Level IV Flat to Rolling Cropland	Bozoisky-II Russian wr
Mandan, ND	46° 48' N, 100° 46' W, elevation 510 m	41.4 cm	Level III Northwestern Glaciated Plains, Level IV Collapsed Glacial Outwash	Bozoisky-II Russian wr
Miles City, MT	46° 22' N, 105° 5' W, elevation 721 m	33.0 cm	Level III Northwestern Great Plains, Level IV River Breaks	Bozoisky-II Russian wr

wg = wheatgrass; wr = wildrye

5.4 Field testing

Field testing consisted of measurements of plant stands for several years after the various monoculture germplasm and seeding mixtures were sown. After the Stryker tracking event at YTC in 2005, plots were measured for two additional years. Table 9 summarizes the activities and data taken at the various field sites. Descriptions of the activities are given in the sections below; measurement protocol is described in Section 5.5.

Table 9. Time line of field events.

	YTC – Exit 11	Fort Guernsey – River site	Fort Guernsey –Tower site	Dugway Proving Grounds	Fort Drum – Airport site	Fort Drum – Area 8 site
2002 – Spring	rototilled				Mixes seeded (22 May)	Mixes seeded (22 May)
Summer	Roundup® & Trimec® (one spraying)					
Fall	Monocultures & mixes seeded (Oct 21-22)					

	YTC – Exit 11	Fort Guernsey – River site	Fort Guernsey –Tower site	Dugway Proving Grounds	Fort Drum – Airport site	Fort Drum – Area 8 site
2003 – Spring	Establishment measurements (14 May)	Rototilled				
Summer		Roundup® & Trimec® (three sprayings)			1-year measurements (24 June)	1-year measurements (24 June)
2004 – Spring	1-year measurements (19 April)	Monocultures & mixes seeded (31 March) Establishment measurements (2 June)	Rototilling			
Summer			Roundup® & Trimec® (three sprayings)		2-year measurements (29 June)	No measurements (site was used for training)
2005 – Spring	2-year measurements (2 June) Stryker tracking (14 June)	1-year measurements (2 June)	Monocultures & mixes seeded (23 March) Establishment measurements (2June)			
Summer				Rototilled	3-year measurements (7 Sept)	
Fall				Monocultures seeded (7 Nov)		
2006 – Spring	Stand frequency 1 year after tracking			Establishment measurements (10 May)	4-year measurements (7 June)	
Summer		2-year measurements (19 July)	1-year measurements (19 July)			
2007 - Spring	Stand frequency 2 years after tracking		No measurements due to drought conditions	No measurements		

5.4.1 Field evaluations of new germplasms: comparisons of germplasms with existing cultivars (monocultures) — testing

Evaluations of monocultures at YTC and Guernsey consisted of measurements taken annually (spring) over a 2-year period, except at the Tower site at Guernsey where we were unable to take 2-year measurements due to drought. At Dugway, we took establishment measurements, but no further data as the establishment was very poor. The data collected included establishment and persistence of sown species. Establishment and persistence were recorded as percent cover, measured either by using modified Vogel frames of different sizes or by visual ratings (both protocols are described in Section 5.5 below). We also recorded percent bare ground, percent dead plants, and percent weeds in many instances.

5.4.2 Ecological-bridge demonstration (mixtures) — testing

The establishment of plants during the first growing season, 2–6 months after seeding, was measured at YTC and Camp Guernsey by taking frequency measurements of total plants. At both sites, we used a 48-grid frame of 6.35 x 6.35-cm (2.5 x 2.5-in.) squares (see Section 5.5.1 on the modified Vogel frame) for the establishment measurements. It was not possible to distinguish among the different species during the early stage of growth when planting seed mixtures. Following the establishment year, we took spring or summer measurements for the next 2 years with a 24-grid frame of 12.7 x 12.7-cm (5 x 5-in.) squares at YTC and at Camp Guernsey in 2005. In 2006 at Camp Guernsey, we took visual ratings for the 2-year River site measurements and 1-year Tower site measurements; we were unable to take 2-year measurements at the Tower site due to drought conditions.

At Fort Drum, we took measurements for 4 years at the Airport site; Area 8 was used for training after the first year, so we have only 1-year measurements for that site. We measured plant cover of sown species, bare ground, and weedy species at all three facilities. The first-year measurements were taken with a 24-grid frame of 12.7 x 12.7-cm (5 x 5-in.) squares; in the remaining years, we used a 36-grid frame of 12.7 x 12.7-cm (5 x 5-in.) squares (see Section 5.5.1 on the modified Vogel frame); at least five samples were taken per plot.

5.4.3 Military traffic on monocultures at YTC — testing

On 2 June 2005, we made a reconnaissance of the site to determine the condition of the species and to see if it was a good time to do the traffic experiment. The vegetation was very uneven, and several species were nearly gone. Precipitation on the plots had been sparse for some time, and the soil was very dry. Only a few plots with Vavilov and SERDP-modified Vavilov Siberian wheatgrass, SERDP western wheatgrass, and Bozoisky (Syn A) Russian wildrye were reasonably covered.

A Stryker was used to track the plot on 14 June 2005. The vehicle has a 2.25-m (7.4-ft) track width and 38-cm (15-in.) tire width when loaded. Rates of tracking and the vehicle velocity required to achieve both light and heavy treatments were determined in the field outside of the plot area. These off-site tests showed that straight tracks of one and four passes per replication at a vehicle speed of 20 mph produced sufficiently different rutting.

Traffic patterns were set up such that three rates of disturbance—zero pass, one pass, and four passes—would be applied per replication – a total of 12 treatments. Disturbance rates were randomly applied to each replication and perpendicular to planted entries (Figure 9).

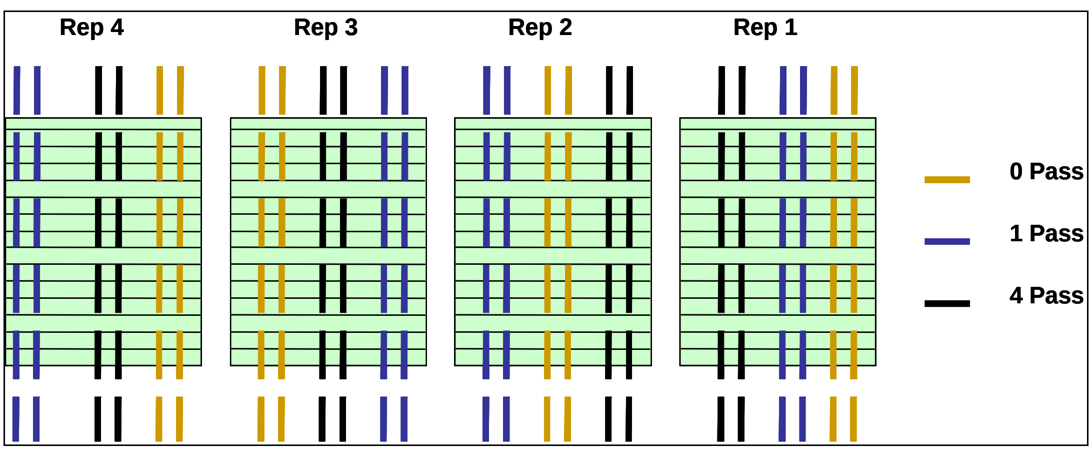

Figure 9. Traffic design at YTC Exit 11 (Note: Plot 1, Rep 1 is in the lower right corner; plot numbers go from the bottom up).

Measurements taken before and after the traffic passes and both 1 and 2 years after the event are summarized in Table 10. The locations of the measurements in relation to the ruts are shown in Figure 10. The measurement protocols are described in Section 5.5.

Table 10. Soil and vegetation measurements before and after traffic event (June 2005), YTC Exit 11.

Characteristic	Protocol	Before	Immed. after	After 1 yr	After 2 yr
Soil characterization					
Shear strength	Pilcon shear vane	X		X	X
Soil moisture	Delta T ML2x moisture probe	X		X	X
Soil bulk density	Drive-cylinder, 283-cc soil cores	X			
Soil compaction	Drop-cone penetrometer		X	X	X
Rut depth	Pin profilometer		X	X	X
Vegetation response					
Plant resiliency	Percent cover	X	X	X	X

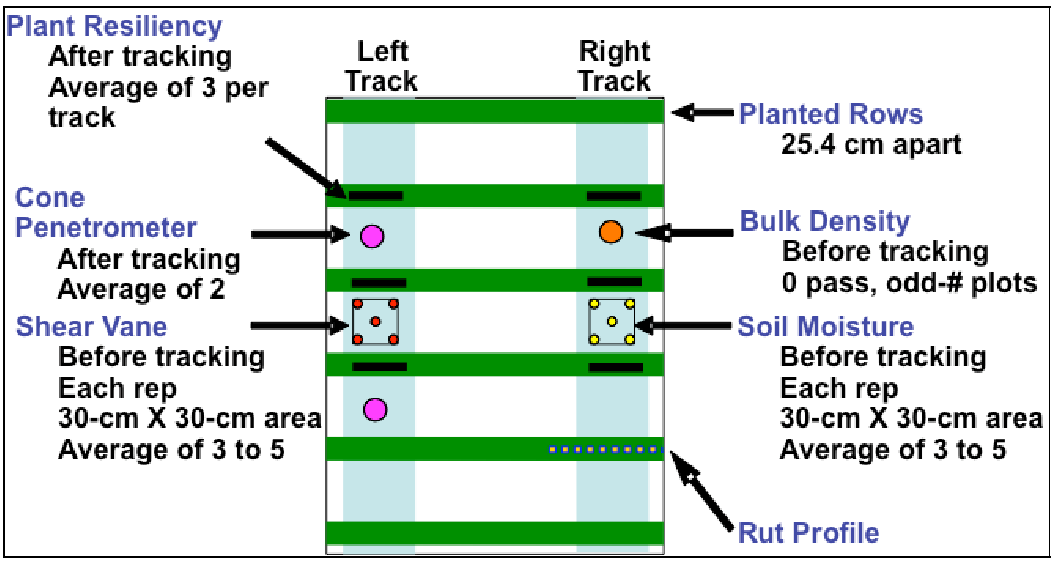

Figure 10. Location of sampling points before and after tracking; green represents planted rows, which are perpendicular to the tracking ruts.

The soil-characterization measurements were made to fully define the soil conditions prior to tracking so that the degrees of vehicle impacts from future tracking experiments could be compared to the soil conditions and correlations defined.

In 2006 and 2007 (1 and 2 years after tracking) soil physical properties (shear strength, soil moisture and compaction) were remeasured, with the exception of soil bulk density. Rut profiles were also remeasured to determine changes in the profile over time.

To measure rebound of the planted species, the three center rows of each track were measured using the 12.5 x 12.5 cm (5 x 5-in.) grid to determine the percent cover. The two tracks were then averaged to determine percent cover for each species.

5.4.4 Cultivar validation: Germination and nursery-field studies — testing

In the germination studies in the CRREL environment chambers, plant root initiation for the seed was determined according to the AOSCA (2003). Each growth pouch was examined daily for up to 28 days.

In the space-planted field trials for cultivar evaluation, seedling establishment and subsequent stand persistence were measured as plant frequency using a modified Vogel frame (see Section 5.5.1). Seedling frequency was determined with a 48-square grid of 5.1 x 5.1-cm quadrants laid over the drilled rows. This was repeated three times along the 8-m row, for a total of 144 quadrants. The same procedure was used to determine subsequent stand frequency except that the quadrants were 10.2 x 10.2-cm, for a total of 72 quadrants per plot.

All data were subjected to analysis using the MIXED procedure of SAS and replications were considered random, and the SOLUTION option was used to allow estimation of LS-means (SAS Institute Inc., 1999). All mean separations were made on the basis of least significant differences at the 0.05 probability level. Forage yields or dry weights were also measured (see Section 5.5.3).

5.5 Sampling protocol

This section describes each measuring technique used in the various parts of our demonstrations. Sampling dates are given in the timeline in Table 9 above; soil data protocols used before and after tracking are summarized in Table 10 above. Table 11 below summarizes the type of vegetation sampling and number of samples at each demonstration site.

Table 11. Summary of vegetation sampling protocol at each site.

Site	Establishment	1 year	2 years	3 years	4 years
YTC	48-grid frame 4 reps; 4 samples/rep	24-grid frame 4 reps; 3 samples/rep	24-grid frame 4 reps; 5 samples/rep	---	---
Guernsey River site	48-grid frame; 3 reps; 3 samples/rep	24–grid frame 3 reps; 3 samples/rep	Visual ratings (3 teams of 2 people)	---	---
Guernsey Tower site	48-grid frame; 3 reps; 3 samples/rep	Visual ratings (3 teams of 2 people)	---	---	---
Dugway	48-grid frame; 4 reps; 3 samples/rep	---	---	---	---
Fort Drum Area 8	---	24-grid frame; 4 samples/plot	---	---	---
Fort Drum Airport	---	24-grid frame 4 samples/plot	36-grid frame; 4 samples/plot	36-grid frame; 4 samples/ plot	36-grid frame; 4 samples/ plot
YTC tracking plant cover	24-grid frame 4 reps; 5 samples/rep	24-grid frame 4 reps; 3 samples/rep	24-grid frame 4 reps; 3 samples/rep		

5.5.1 Vogel frequency frame (modified)

For most of our establishment and persistent measurements, we used a modified Vogel frame with an internal grid (Vogel and Masters 2001). Different sized grids were used. The grids consist of a metal frame containing 24, 36, or 48 squares created by heavy duty wire; the squares are aligned in a six-by-four, six-by-six, or six-by-eight pattern, and measured 12.7 x 12.7 cm (5 x 5 in.) in the 24-square frame or 6.35 x 6.35 cm (2.5 x 2.5 in.) in the 36- and 48-square frames. We randomly or systematically placed the grid within a seeded area. The number of cells containing plants were counted and converted into frequency of occurrence or stand percentages by dividing the number of cells that contain a seeded plant by the total number of squares counted. Similar methods were used to obtain the percentages of bare ground, dead plants, or weeds.

5.5.2 Visual frequency ratings

At some sites, we recorded a visual rating of ground cover, weeds, litter, and bare ground. Three teams of two rated each plot overall, and their values were used to get the percentages of each condition.

5.5.3 Plant biomass (forage yield)

Plant biomass (forage yield or dry plant matter) was evaluated in the spaced-plant nurseries. At some locations, individual plots were harvested with a sickle-bar harvester to an 8-cm stubble height just prior to anthesis. Forage samples were taken from each plot and dried to a constant weight in a forced-air oven at 60 °C for 48 hours to determine dry matter percentage.

5.5.4 Shear strength

Soil shear strength was measured with a Pilcon shear vane (ELE model CL-612 Hand Vane Tester). Measurements were made in three to five locations in a 30.5 x 30.5-cm (12 x 12-in.) area from the center of the right track in each plot (Figure 10). The five values were then averaged to give the shear strength for that location. Soil shear strength at YTC Exit 11 was taken immediately before the June 2005 traffic event.

5.5.5 Soil moisture

Soil moistures were measured in the same three- to five-measurement pattern (Figure 10) with a Delta T type ML2x probe/HH2 moisture meter from each replication prior to tracking and averaged to give the moisture in that plot.

5.5.6 Soil bulk density

Bulk density measurements were taken with a 283 cm^3 drive cylinder corer in the 0-pass treatment, from plots 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19 of each replication prior to tracking (see Table 38 in Appendix Section D.2 for the seeding list by plots).

5.5.7 Soil compaction (penetration resistance)

A drop-cone penetrometer was used to measure soil compaction before tracking in the zero-pass treatment and immediately following tracking in

the low- and high-rate plots. All compaction measurements were taken from the left-hand track (looking in the direction of vehicle movement) with two samples per species (plot) averaged to give depth of penetration for each plot.

5.5.8 Rut depth

Rut profiles were taken from the right-hand track with a pin profilometer as described by Affleck et al. (2004) (Figure 11). Profiles for the four-pass treatments were taken in every plot for all replications, for the 1-pass treatment from plots 4, 8, 12, 16, and 20 for each replication, and for the 0-pass treatments from plots 2, 10 and 18 (see Table 38 in Appendix D.2 for the seeding list by plots).

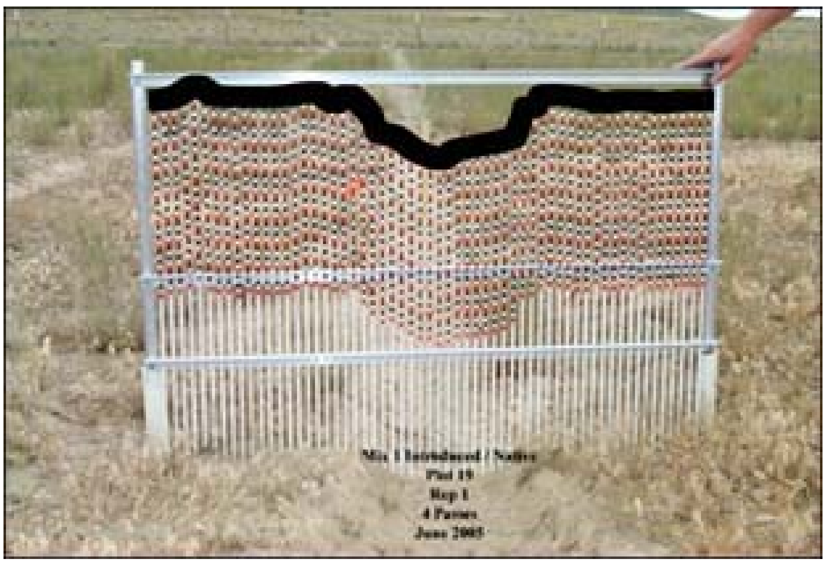

Figure 11. Pin profilometer used in a 4-pass rut immediately after tracking in June 2005.

5.5.9 Statistical analyses

Differences in establishment rates and persistence between the SERDP-select germplasms and standard cultivars were done with multiple means comparison tests (protected LSD). Differences in the establishment rate, growth of invasive plants, and plant regrowth after tracking of the eco-bridge seeds were subjected to analysis of variance using PROC MIXED (SAS 1999), with entries as fixed and replications and years as random variable effects. Mean separations were made on the basis of the least significant difference (LSD) test at an alpha = 0.05 probability level.

5.6 Sampling results

These sections provide summary data and figures. More detailed data are presented in Appendix D.

All the demonstration plots were seeded before most of the modified germplasms had been named and released. At that time, the modified seeds were referred to as SERDP-select. For clarity in this summary section, we refer to those modified plant materials by their release names, with the exception of Snake River wheatgrass, which has not yet been released or named.

5.6.1 Field evaluations of new germplasms: comparisons of germplasms with existing cultivars (monocultures) — results

5.6.1.1 Yakima Training Center monocultures

Table 12, Figure 12, and Figure 13 show stand establishment and percent stand over 3 years from the Exit 11 seeding on 21–22 October 2002 (full data is given in Appendix D.5). Variety names are given in parentheses; the SERDP-modified entries are shaded in green. The SERDP-modified entries generally did better than the standard cultivars; the SERDP cultivars of Siberian wheatgrass and western wheatgrass had significantly better cover than their counterparts in all 3 years. In the last year (2005), the vegetation was very uneven, several species were nearly gone, and the plots were infested with bill bugs. Precipitation on the plots had been sparse for some time, and the soil was very dry. Only a few plots with Vavilov and SERDP-modified Vavilov-II Siberian wheatgrass, SERDP Recovery western wheatgrass, and SERDP Bozoisky-II parent Russian wildrye were reasonably covered.

Table 12. Establishment and persistence of monocultures for 3 years at YTC Exit 11 (seeded 21–22 October 2002).

Variety	2003	2004	2005	LSD @0.05
Russian wildrye (Bozoisky II)	54	67	73	ns
Russian wildrye (Boz X Tet)	47	60	62	12.33
Siberian wheatgrass (Vavilov II)	52*	63*	73*	ns
Siberian wheatgrass (Vavilov)	23	35	51	9.33
Bluebunch wheatgrass (P-7)	30	47	48	ns
Bluebunch wheatgrass (Goldar)	32	39	40	ns
Slender wheatgrass (FirstStrike)	82*	69	21	15.66
Slender wheatgrass (Pryor)	49	48	28	ns
Snake River wheatgrass (SERDP)	28	41	54	17.49
Snake River wheatgrass (Secar)	40	58	54	13.87
Western wheatgrass (Recovery)	73*	81*	80*	ns
Western wheatgrass (Rosana)	40	53	59	ns
LSD @ 0.05	16.36	27.06	19.29	

* significantly better than the equivalent standard cultivar in that year

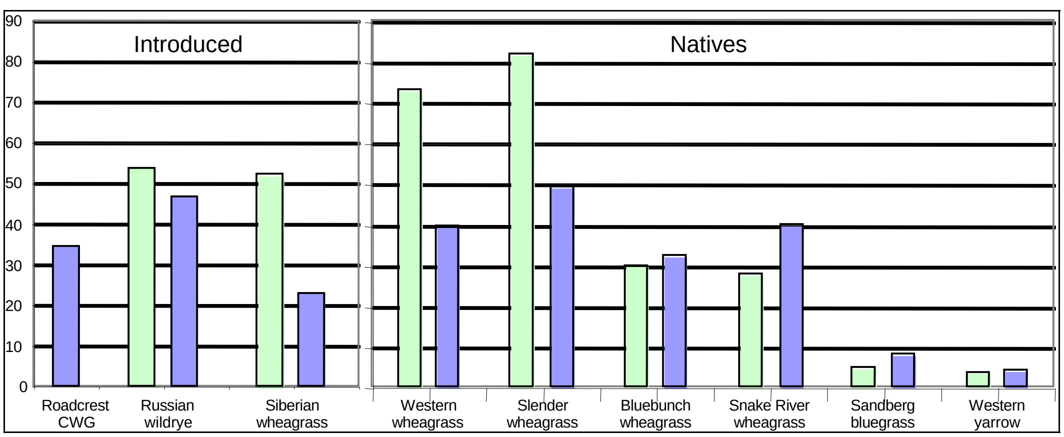

Figure 12. Percent establishment of modified germplasms (green) vs. standard cultivars at Exit 11 YTC in May 2003, 6 months after seeding.

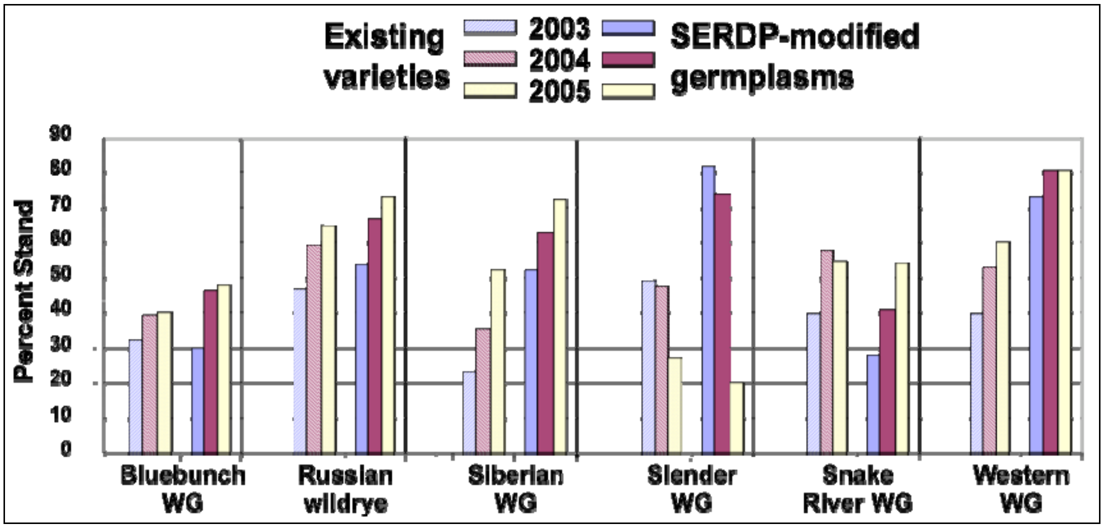

Figure 13. Percent stand vegetation from 2003 to 2005 (before June 2005 tracking at YTC).

5.6.1.2 Camp Guernsey monocultures

Camp Guernsey establishment (2 months after seeding). The River site was seeded 31 March 2004, and establishment measurements were taken 2 June 2004. The Tower site was seeded the following year on 23 March 2005, and establishment measurements were taken 2 June 2005. A 48-grid frame was used to count the number of the 6.35 x 6.35-cm (2.5 x 2.5-in.) squares that were missing plants. Stand frequency was then determined from the mean percentage of squares containing plants.

Our FirstStrike slender wheatgrass established significantly better than Pryor slender wheatgrass at both sites, and our Bozoisky II Russian wildrye established significantly better than the standard Bozoisky cultivar at the River site (Table 13).

Table 13. Camp Guernsey site establishment data at two sites taken 2 months after seeding (River site seeded 31 March 2004, data taken 2 June 2004; Tower site seeded 23 March 2005, data taken 2 June 2005).

Entry	River % stand at 2 mos.	Tower % stand at 2 mos.
Introduced		
Russian wildrye (Bozoisky-II parent)	48*	50
Russian wildrye (Bozoisky)	17	65
Siberian wheatgrass (Vavilov II)	54	68
Siberian wheatgrass (Vavilov)	38	65
Native		
Western wheatgrass (Recovery)	61	51
Western wheatgrass (Rosana)	55	39
Slender wheatgrass (FirstStrike)	81*	62*
Slender wheatgrass (Pryor)	35	37
Bluebunch wheatgrass (P-7)	43	56
Bluebunch wheatgrass (Goldar)	47	55
Snake River wheatgrass (SERDP-select)	5	55
Snake River wheatgrass (Secar)	6	44
Basin wildrye (SERDP-select)	11	40
Basin wildrye (Trailhead Basin)	13	50
Western Yarrow (Yakima)	0	0
Western Yarrow (Check)	0	0
LSD @0.05	19	24

* Significantly better than equivalent standard cultivar

Camp Guernsey persistence data (1 year and 2 years after seeding). Table 14 shows the 1-year data from both River and Tower sites; Table 15 shows 2-year data for the River site. We were unable to measure the Tower site after 2 years (2007) due to drought conditions. The 1-year percent stand at the River site was measured with a 24-grid frame of 12.7 x 12.7-cm (5 x 5-in.) squares; both visual ratings and frame data were taken for the remaining data.

After 1 year, our Bozoisky II Russian wildrye again had significant greater stand and fewer weeds than did the standard Bozoisky cultivar. After 1 and 2 years at the River site, our FirstStrike slender wheatgrass had significantly fewer weeds than did Pryor slender wheatgrass; after 2 years, FirstStrike had a significantly greater stand frequency than Pryor.

Table 14. Camp Guernsey site persistence data at two sites taken 1 year after seeding (River site seeded 31 March 2004, data taken 2 June 2005; Radar site seeded 23 March 2005, data taken 19 July 2006).

Entry	River site at 1 yr (mean percent) Stand	River site at 1 yr (mean percent) Seeds (visual estimate)	Tower site at 1 yr (mean percent) Stand	Tower site at 1 yr (mean percent) Weeds (visual est.)
Introduced				
Russian wildrye (Bozoisky-II parent)	61*	30*	81	3
Russian wildrye (Bozoisky)	26	75	82	1
Siberian wheatgrass (Vavilov II)	68	2	91	4
Siberian wheatgrass (Vavilov)	63	2	77	3
Native				
Western wheatgrass (Recovery)	73	30	74	7
Western wheatgrass (Rosana)	77	30	78	3
Slender wheatgrass (FirstStrike)	65	17*	89	1
Slender wheatgrass (Pryor)	44	50	65	4
Bluebunch wheatgrass (P-7)	55	40	76	3
Bluebunch wheatgrass (Goldar)	38	37	81	2
Snake River wheatgrass (SERDP-select)	13	77	80	4
Snake River wheatgrass (Secar)	8	73	70	6
Basin wildrye (SERDP-select)	10	78	19	14
Basin wildrye (Trailhead Basin)	10	77	25	10
Western yarrow (Yakima)	0	90	1	22
Western yarrow (common variety)	0	87	3	22
LSD @0.05	26.8	26.7	26.7	7.9

* Significantly better than equivalent standard cultivar

Table 15. Camp Guernsey River site persistence data 2 years after seeding (seeded 31 March 2004; data taken 19 July 2006).

Entry	Mean percent (visual rating) Cover	Weeds	Litter	Bare ground	Frame measurement percent stand
Introduced					
Russian wildrye (Bozoisky-II parent)	37	0	28	35	66*
Russian wildrye (Bozoisky)	24	4	21	51	32
Siberian wheatgrass (Vavilov II)	41	1	20	39	68
Siberian wheatgrass (Vavilov)	38	1	16	46	55
Native					
Western wheatgrass (Recovery)	44	1	23	31	91
Western wheatgrass (Rosana)	40	1	25	34	83
Slender wheatgrass (FirstStrike)	37	1*	19	43	62*
Slender wheatgrass (Pryor)	14	19	32	34	31
Bluebunch wheatgrass (P-7)	28	5	26	41	50
Bluebunch wheatgrass (Goldar)	24	7	19	50	43
Snake River wheatgrass (SERDP-select)	7	26	27	41	14
Snake River wheatgrass (Secar)	14	13	32	41	23
Basin wildrye (SERDP-select)	3	29	22	46	6
Basin wildrye (Trailhead Basin)	13	28	25	33	12
Western yarrow (Yakima)	0	35	32	33	3
Western yarrow (common variety)	0	36	31	34	0
LSD @0.05	16.5	17.3	ns	ns	29.8

* Significantly better than equivalent standard cultivar

5.6.1.3 Dugway Proving Ground monocultures

We took establishment data only at DPG. The establishment was poor across all species at this very dry facility, so no further data were collected. The site was seeded 7 November 2005, and the establishment data taken 10 May 2006. Percent cover was obtained with a 48-grid frame with 6.35 x 6.35-cm (2.5 x 2.5-in.) squares. Establishment was poor overall, and the only significant differences between entries of the same species were for Siberian wheatgrass and slender wheatgrass (Table 16).

Table 16. Dugway Proving Ground establishment data 6 months after seeding (seeded 7 November 2005; data taken 10 May 2006).

Entry	Percent stand
Introduced	
Russian wildrye (Bozoisky-II)	15.5
Russian wildrye (Bozoisky)	17.9
Siberian wheatgrass (Vavilov II)	33.3*
Siberian wheatgrass (Vavilov)	17.9
Native	
Western wheatgrass (Recovery)	11.6
Western wheatgrass (Rosana)	6.9
Slender wheatgrass (FirstStrike)	11.8
Slender wheatgrass (Pryor)	23.3
Bluebunch wheatgrass (P-7)	12.5
Bluebunch wheatgrass (Goldar)	4.9
Snake River wheatgrass (BC04)	9.4
Snake River wheatgrass (Secar)	8.2
Basin wildrye (SERDP-select)	6.9
Basin wildrye (Trailhead Basin)	7.6
Western yarrow (Yakima)	0.3
Western yarrow (common variety)	0.0
LSD @0.05	7.7

* significantly greater than the equivalent standard cultivar

5.6.2 Ecological-bridge demonstration (mixtures) — results

We were able to obtain 4 years of data on mixtures only at the Fort Drum Airport site. Our mixture evaluations at YTC and Camp Guernsey were hampered by severe drought conditions, and our second Fort Drum site was trained on after the first year.

5.6.2.1 Yakima Training Center mixes

The following data (Table 17) were obtained for mixes planted at YTC in October 2002. See Table 5 for a list of the plants included in each mixture. There were no significant differences in the two mixtures in each year after seeding.

Table 17. YTC mixtures approximately 6 months, 1.5 years, and 2.5 years after seeding.

Mixture	Mean percent stand (May 2003)	Mean percent stand (April 2004)	Mean percent stand (June 2005)
Mix 1 – Introduced/native	44	55	59
Mix 2 – All native	44	58	58

5.6.2.2 Camp Guernsey mixes

The following data were obtained for the River Site at Camp Guernsey planted 31 March 2004. See Table 5 and Table 6 for lists of the plants included in each mixture.

At the River site (Table 18), the core native mix with our Bozoisky II Russian wildrye (mix 7) appeared to do the best overall for percent stand and inhibition of weeds, although there were no significant differences in establishment or weed control after the establishment year. The standard Guernsey mix 3 had significantly lower establishment than all the other mixes, which had no significant differences among them.

Table 18. Camp Guernsey River site mixtures 2 months and 1 and 2 years after seeding (seeded 31 March 2004).

Mixture		Mean percent stand	Mean percent weeds
June 2, 2004 (2 months after seeding)			
Mix 1 - Introduced / native		42	
Mix 2 – All native		51	
Mix 3 - Guernsey		16	
Mix 4 - Core native		55	
Mix 5 - Core + AI Intermediate wheatgrass		54	
Mix 6 - Core + Vavilov II Siberian wheatgrass		58	
Mix 7 - Core + Bozoisky II Russian wildrye		57	
	LSD @ 0.05	19.8	
June 2, 2005 (1 year after seeding)			
Mix 1 – Introduced / native		63	17
Mix 2 – All native		76	30
Mix 3 - Guernsey		41	45
Mix 4 - Core native		63	37
Mix 5 - Core + AI Intermediate wheatgrass		73	22
Mix 6 - Core + Vavilov II Siberian wheatgrass		48	32
Mix 7 - Core + Bozoisky II Russian wildrye		71	17
	LSD @ 0.05	ns	ns
June 2006 (2 years after seeding) (Visual ratings)			
Mix 1 – Introduced / native		35	2
Mix 2 – All native		26	14
Mix 3 - Guernsey		41	4
Mix 4 - Core native		37	4
Mix 5 - Core + AI Intermediate wheatgrass		26	2
Mix 6 - Core + Vavilov II Siberian wheatgrass		34	5
Mix 7 - Core + Bozoisky II Russian wildrye		43	0
	LSD @ 0.05	ns	ns

At the Tower site (Table 19), the introduced-native mix tested at YTC provided the best stand both initially and after 1 year. After 1 year, the introduced-native mix 1 was significantly better than both the native-only mix 2 and the Guernsey mix 3. The standard Guernsey mix 3 had a significantly lower stand than all the other mixes after 1 year. There were very few weeds with any of the mixes and no significant differences among the mixes. The decrease across all mixes in 2006 may have reflected the

beginning of drought; because of severe dryness, we were unable to obtain any data in 2007.

Table 19. Camp Guernsey Tower site mixtures 2 months and 1 year after seeding (seeded 23 March 2005).

Mixture	Mean percent stand	Mean percent weeds
June 2, 2005 (2 months after seeding)		
Mix 1 - Introduced / native	57	
Mix 2 – All native	50	
Mix 3 - Guernsey	25	
Mix 4 - Core native	47	
Mix 5 - Core + AI Intermediate wheatgrass	42	
Mix 6 - Core + Vavilov II Siberian wheatgrass	44	
Mix 7 - Core + Bozoisky II Russian wildrye	45	
LSD @ 0.05	ns	
June 2006 (1 year after seeding) (Visual estimates)		
Mix 1 – Introduced / native	28	4
Mix 2 – All native	17	5
Mix 3 - Guernsey	9	5
Mix 4 - Core native	23	4
Mix 5 - Core + AI Intermediate wheatgrass	19	4
Mix 6 - Core + Vavilov II Siberian wheatgrass	24	4
Mix 7 - Core + Bozoisky II Russian wildrye	17	7
LSD @ 0.05	10.6	ns

5.6.2.3 Fort Drum mixes

We took data at the Airport site for 4 years after the 22 May 2002 seeding, but were only able to obtain data at the Area 8 site for 1 year. The Area 8 site had a good plant cover after the first year and was used for training after that.

Even after 1 year (Table 20; Table 52 in Appendix D.7), the native switchgrass was doing very well, especially on the Area 8 site; the fescues were also doing well. The weeping lovegrass was beginning to die back at both sites. The hairgrasses established in only one plot (plot 4 with weeping lovegrass and switchgrass at Area 8).

Table 20. Fort Drum Area 8: 1-year site percent cover and bare ground on 24 June 2003.

	Treatment	WL	FF	SG	HG	Total sown species	Other species	Dead WL	Bare ground
1	Weeping lovegrass	16	–	–	--	16	1	77	6
2	Weeping lovegrass + hairgrass	19	–	–	0	19	42	35	4
3	Weeping lovegrass + switchgrass	6	–	83	--	88	0	11	1
4	Weeping lovegrass + switchgrass + hairgrass	1	–	83	4	87	0	12	0
5	Weeping lovegrass + hairgrass + switchgrass + fine fescues	0	42	2	0	44	0	44	2
6	Weeping lovegrass + hairgrasses + fine fescues	5	10	--	0	17	70	9	4
7	Weeping lovegrass + switchgrass + fine fescues	4	62	2	–	64	0	33	2
8	Weeping lovegrass + fine fescues	54	18	–	--	58	0	42	0
	LSD @ 0.05	17	24	15	ns	23	13	20	ns

Detailed data with statistics for the 4 years (2003–2006) at the Fort Drum airport site are shown in Appendix Section D.7. The weeping lovegrass had died off in all plots and the fescues were doing well in all plots where it was sown; the native hairgrass failed in all plots. Percentages of undesired (other) species were low in all plots except plot 2, which was sown with weeping lovegrass with hairgrass, both of which had died off. Figure 14 separates the results for the four plots (3, 4, 5, and 7) that contained switchgrass. After 4 years, the switchgrass was doing significantly better in those plots that did not contain fescues (3 and 4). In summary, the nurse

crop did well during the initial year after seeding but was no longer competitive after 2 years; stands of predominately switchgrass or fescues were created, giving a choice for the desired goal—a tall native stand or a lower growing more fire resistant stand of fescues.

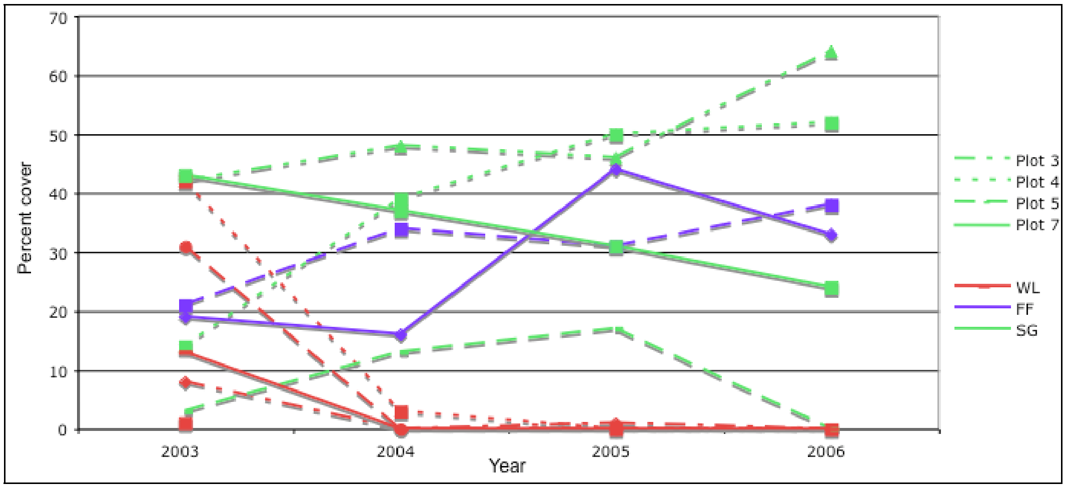

Figure 14. Airport site percent cover on the four plots seeded with switchgrass (see Table 7 for seeding mixtures).

5.6.3 Military traffic on monocultures at YTC — results

Plots at YTC were tracked with 0, 1, or 4 passes in June 2005. Soil and vegetation data were taken immediately before and after tracking as well as 1 and 2 years later (June 2006 and 2007).

5.6.3.1 Soil data

There were no significant differences in soil compaction by plant entry (Table 55 in Appendix Section D.8). Overall, increased tracking significantly decreased the soil strength and compaction immediately after the tracking (Figure 15 and Table 21); tracking with a Stryker was similar to a tillage operation causing the soil to be fluffier with increasing passes. Shear vane measurements could not be taken immediately after tracking because of the soil disturbance. In succeeding years, any differences in soil compaction between treatments were slight, and the cone penetrometer values for the 4-pass treatment were essentially the same as the control (0-pass).

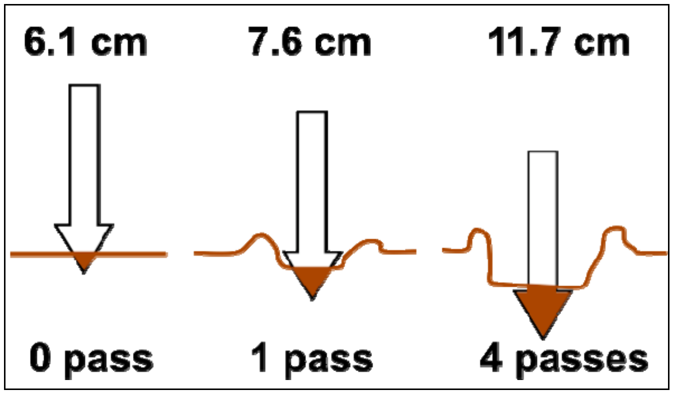

Figure 15. Mean soil compaction results in ruts immediately after June 2005 tracking at YTC (the deeper the penetrometer depth, the less compact the soil).

There was a significant increase in soil moisture in 2006 due to unexpectedly high rainfall (Table 21). The cone penetrometer data showed significantly decreased soil compaction along with the increased soil moisture. By the following year, the soil was more compact, with values very close to those for 2005.

Table 21. Overall soil properties over 3 years after tracking in June 2005.

		Shear vane (kPa)				Cone penetrometer (cm)			
Year	Soil moisture (%)	0 pass	1 pass	4 pass	LSD @0.05	0 pass	1 pass	4 pass	LSD @0.05
2005	2.8	38.8	--	--	--	6.1	7.6	11.7	0.5
2006	14.3	38.1	36.4	24.6	ns	13.4	12.1	13.0	0.4
2007	3.3	37.6	35.8	24.1	ns	7.5	7.1	7.5	0.2
LSD @ 0.05	0.1	ns	.55	ns		0.5	0.4	0.5	

Rut depth profiles did not differ significantly in the years following tracking, but mean rut depth (7 cm) after the 4-pass treatment was significantly different than for the 1-pass treatment (4.2 cm) for all entries (Table 56 in Appendix Section D.8). The modified cultivars of Siberian wheatgrass, slender wheatgrass and Snake River wheatgrass had significantly lower rutting at 1-pass treatment than their market competitors. Likewise the modified cultivars of Siberian wheatgrass, Russian wildrye, slender wheatgrass, and western wheatgrass had significantly lower rutting than their market counterparts at the 4-pass treatment. The decreased rutting at 1- and 4-pass treatments indicates

better root structure and resiliency than the other cultivar (See Table 56 in Appendix D.8).

The mean value for soil bulk density (taken in 0-pass treatments in 2005) was 1.098 g/cm^3.

5.6.3.2 Vegetation data

A summary of all plant cover data for the 3 years shows that each level of tracking was significantly different (Table 22). Similarly, there were significant differences in overall plant cover each year, showing the impact of heavy rains in 2006. The percentage of cover jumps from 38.7% to 51.3% (for all varieties and tracking levels combined), and then goes down to 44.4% for 2007. This effect is mirrored in soil moisture data (Table 21).

Table 22. Summary data for tracking and annual effects on plant cover at YTC.

Tracking effect		Yearly effect	
Tracking	% Cover	Year	% Cover
0 pass	51.1	2005	38.7
1 pass	26.4	2006	51.3
4 passes	4.28	2007	44.4
LSD @ 0.05	5.11	LSD @ 0.05	4.28

Vegetative cover in the 3 years leading up to tracking is shown above in Section 5.6.1.1 (Table 12, Figure 12, and Figure 13). The SERDP-modified entries generally did better than the standard cultivars; the SERDP cultivars of Siberian wheatgrass and western wheatgrass had significantly better cover than their counterparts in all 3 years before tracking.

Throughout the post-tracking evaluations, three SERDP-modified entries—Snake River wheatgrass, Siberian wheatgrass, and Russian wildrye—performed better than the standard variety counterparts. Figure 16 compares the plant varieties for all tracking treatments combined immediately after and 1 year following tracking, and Table 23 shows the same comparisons for the duration of the tracking evaluation (2005-2007). Of note overall is the SERDP Snake River wheatgrass (74.1%) versus Secar Snake River wheatgrass (48.9 %) and SERDP Siberian wheatgrass Vavilov II (72.5%) versus the standard Vavilov (45.5%). Both

slender wheatgrass entries were low throughout, likely because of poor performance in the dry conditions preceding the tracking event.

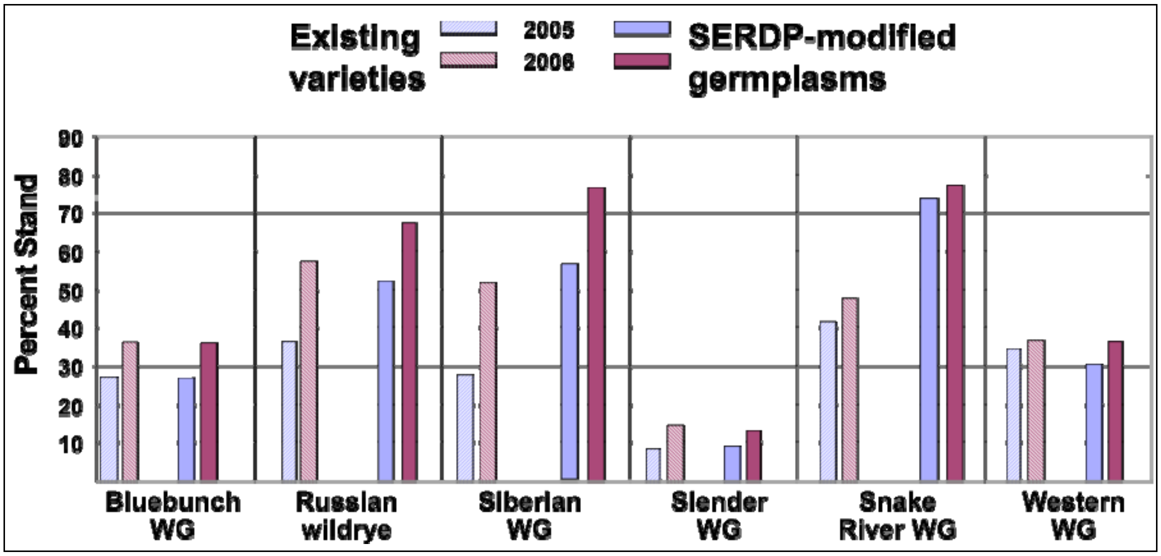

Figure 16. Percentage stand for vegetation immediately after and 1 year following 2005 tracking at YTC (Figure 13 shows percentage stand for 2003–2005 before tracking).

Table 23. Summary of plant cover for each entry at YTC over all treatments for 3 years after tracking (2005-2007).

Entry	% Cover
Bluebunch wheatgrass (P-7)	36.6
Bluebunch wheatgrass (Goldar)	34.1
Russian wildrye (Bozoisky II)	59.7*
Russian wildrye (BozXTet)	43.7
Siberian wheatgrass (Vavilov II)	72.5*
Siberian wheatgrass (Vavilov)	45.4
Slender wheatgrass (FirstStrike)	12.6
Slender wheatgrass (Pryor)	13.5
Snake River wheatgrass (SERDP)	74.1*
Snake River wheatgrass (Secar)	48.9
Western wheatgrass (Recovery)	43.7
Western wheatgrass (Rosana)	53.8
LSD @ 0.05	8.57

Significantly greater than the standard cultivar entry for this species.

Looking at tracking effects, all entries (except for Pryor slender wheatgrass) had significantly less cover at the 4-pass treatment as compared to the 1-pass treatment (Table 24). Most entries had no significant difference in cover between the no-pass control and 1-pass treatment. Three of the SERDP-modified entries—Bozoisky II Russian wildrye, Vavilov II Siberian wheatgrass, and SERDP-select Snake River wheatgrass—did significantly better than the commonly available varieties for all treatments.

Table 24. Varieties showing significant differences at the different tracking passes over 3 years of data (2005–2007) after tracking at YTC.

Entry	Tracking 0 pass	 1 pass	 4 pass	LSD @0.05
Bluebunch wheatgrass (P-7)	63*	44.4	3.2	5.6
Bluebunch wheatgrass (Goldar)	41.2	47.2	13.9	16.5
Russian wildrye (Bozoisky II)	75.9*	63.9*	39.3*	15.8
Russian wildrye (BozXTet)	49.5	55.1	26.4	15.1
Siberian wheatgrass (Vavilov II)	81.5*	77.8*	58.3*	7.2
Siberian wheatgrass (Vavilov)	61.6	59.3	15.3	8.3
Slender wheatgrass (FirstStrike)	23.1	13.9	0.9	6.6
Slender wheatgrass (Pryor)	17.1	13.9	9.7	8.6
Snake River wheatgrass (SERDP)	78.2*	80.1*	63.9*	5.5
Snake River wheatgrass (Secar)	56	57.4	33.3	9.7
Western wheatgrass (Recovery)	64.8	48.6	17.6	6.9
Western wheatgrass (Rosana)	71.7	51.4	35.2	10.9
LSD @ 0.05	10.4	9.4	9.1	

* significantly better than the equivalent standard cultivar for that treatment

5.6.4 Cultivar validation: germination and nursery-field studies — results

5.6.4.1 Germination studies

In the growth-pouch germination studies, germination occurred at all the temperatures—10, 15, 20, 25, and 30 °C (33.8, 59, 68, 77, and 86 °F)—but there were significant differences between the lower and higher temperatures. The greatest percent germination occurred at 15 °C; the next highest rates were at 10 °C and 20 °C. Although germination

occurred sooner at the higher temperatures, the percent germination was significantly lower at the two highest temperatures (Table 25).

Table 25. Temperature effects on all entries combined in germination growth pouch studies.

Temperature	Average time to germination (days)	Percent germination
10 °C	6.4	70.9
15 °C	5.7	76.2
20 °C	4.6	68.7
25 °C	4.8	58
30 °C	5.1	40.6
LSD @0.05	0.45	2.9

Table 26 and Table 27 compare our four cultivars plus our modified Snake River wheatgrass (a potential cultivar) with currently available cultivars at the five temperature variables (green shading indicates our cultivars). FirstStrike slender wheatgrass germinated earlier than Pryor at the three lower temperatures. For the other species comparisons, there were no significant differences in time to germination at the individual temperatures (Table 26).

Table 26. Species comparisons of average days to germination in growth pouch studies.

Entry	10 °C	15 °C	20 °C	25 °C	30 °C	All temps
	Days to germination					
Russian wildrye (Bozoisky II)	6.2	4.7	3.1	3.4	4.5	4.4
Russian wildrye (Bozoisky)	5.7	5	3.2	3.2	4.6	4.3
LSD @ 0.05	ns	ns	ns	ns	ns	ns
Siberian wheatgrass (Vavilov II)	4.9	4.3	3.5	3.4	4.2	4.1
Siberian wheatgrass (Vavilov)	5.3	4.6	3.6	3.8	4.1	4.3
LSD @ 0.05	ns	ns	ns	ns	ns	0.18
Slender wheatgrass (FirstStrike)	5.6	5	4.6	4.6	6.2	5.2
Slender wheatgrass (Pryor)	11.6	11.6	10.3	7.1	0	8.1
LSD @ 0.05	2.3	0.1	2.8	ns	2	1.7
Snake River wheatgrass (SERDP)	4.3	3.9	3.1	3.7	4.4	3.9
Snake River wheatgrass (Secar)	4.5	4	4.1	5.1	5.3	4.6
LSD @ 0.05	ns	ns	ns	ns	ns	0.3
Western wheatgrass (Recovery)	7	6	4.7	4.9	7.7	6.1
Western wheatgrass (Rosana)	8.4	7.3	4.3	5.3	7.2	6.5
LSD @ 0.05	ns	ns	ns	ns	ns	ns

For percent germination, our FirstStrike slender wheatgrass outperformed Pryor at all temperatures; both cultivars did poorly at the higher temperatures, but FirstStrike still outperformed Pryor. Our modified Snake River wheatgrass entry also outperformed Secar at all temperatures except 10 °C where there was no significant difference between the two. For the remaining entries, our modified cultivars were the generally same or slightly better for percent germination than the standard cultivars, although Bozoisky Russian wildrye had significantly greater percent germination at 10 °C than did our Bozoisky II entry and Rosana western wheatgrass outperformed Recovery at the higher temperatures (Table 27).

Table 27. Species comparisons of average percent germination in growth pouch studies.

Entry	Percent germination					
	10 °C	15 °C	20 °C	25 °C	30 °C	All temps
Russian wildrye (Bozoisky II)	57.5	74	86	62	68.5	69.6
Russian wildrye (Bozoisky)	92.5	96	88	95.2	78.5	89.5
LSD @ 0.05	24.7	ns	ns	ns	ns	6.4
Siberian wheatgrass (Vavilov II)	95.5	93	96	94	77	91.1
Siberian wheatgrass (Vavilov)	88.5	89	91	85	71	84.9
LSD @ 0.05	ns	ns	ns	ns	ns	3
Slender wheatgrass (FirstStrike)	89	94	81	66.5	33.5	89
Slender wheatgrass (Pryor)	38.5	50	14	3	1	38.5
LSD @ 0.05	14.3	3.7	16.5	14.5	28.7	14.3
Snake River wheatgrass (SERDP)	90	93	90	86.5	61.5	84.2
Snake River wheatgrass (Secar)	87	83	74	62.5	39	69.1
LSD @ 0.05	ns	8.1	11	10.7	18.1	4.2
Western wheatgrass (Recovery)	38.5	59	36	12	4.5	30
Western wheatgrass (Rosana)	31.5	43	31	36	18	31.9
LSD @ 0.05	ns	11	ns	20.3	ns	ns

When all entries were compared together over all temperatures combined, three of our four modified native germplasms ranked in the top six for percent germination (Table 28).

Table 28. Overall comparisons with all temperatures combined in germination growth pouch studies.

Entry	Average time to germination (days)	Percent germination	Percent rank
Basin Wildrye (SERDP)	6.7	38.6	
Great Basin Wildrye (Magnar)	5.6	71.5	6
Russian Wildrye (Bozoisky II)	4.4	69.6	
Russian Wildrye (Bozoisky)	4.3	89.5	2
Slender wheatgrass (FirstStrike)	5.2	72.8	5
Slender wheatgrass (Pryor)	8.1	21.3	
Snake River wheatgrass (SERDP)	3.9	84.2	4
Snake River wheatgrass (Secar)	4.6	69.1	
Siberian wheatgrass (Vavilov II)	4.1	91.1	1
Siberian wheatgrass (Vavilov)	4.3	84.9	3
Western wheatgrass (Recovery)	6.1	30	
Western wheatgrass (Rosana)	6.5	31.9	
LSD @0.05	0.7	4.6	

5.6.4.2 Space-planted nursery studies

Data gathered in these trials were used, along with morphological and genetic characteristics, to support the releases of four cultivars under the ESTCP program. Nursery sites are described in Section 5.3.4 (Table 8).

Recovery western wheatgrass was selected for plant and seedling vigor, increased germination, and seed yield. During the spring of the establishment year, Recovery western wheatgrass had significantly higher ($P \leq 0.05$) frequency of seedlings (0.60) than parental/closely-related cultivars Rosana (0.48) and Rodan (0.45), and the western wheatgrass cultivars of Arriba (0.45), Barton (0.42), and Flintlock (0.53) when analyzed across all locations (Table 60 in Appendix Section D.9). Within locations, Recovery had significantly better establishment than Rodan in three of five test locations, and more than Rosana in three of eight test locations (Table 60 in Appendix Section D.9). On average, Recovery's establishment was better than Bozoisky Russian wildrye, similar to Bozoisky II and Vavilov Siberian wheatgrass, and lower than Vavilov II and Hycrest and Hycrest II crested wheatgrasses (Table 60 in Appendix Section D.9).

Seedlings can have difficulties surviving the first year after planting due to competition from invasive annual and biennial grasses and forbs that benefit from the disturbed, open environment. Across locations, Recovery western wheatgrass had significantly ($P \leq 0.05$) more surviving plants (frequency of 0.77) the year after establishment than parental/closely-related cultivars Rosana (0.68) and Rodan (0.66), and the western wheatgrass cultivars of Arriba (0.63), Barton (0.68), and Flintlock (0.66) (Table 61 in Appendix D.9). In fact, Recovery had higher frequency ($P \leq 0.05$) of plants than any other western wheatgrass cultivar until the fourth to sixth year after planting (Figure 17).

Forage yield (dry matter yield) of Recovery western wheatgrass was not significantly different than other western wheatgrass cultivars at the nursery sites at Blue Creek, UT and the Curlew Valley, ID with the exception of a higher yield than Rosana at Curlew Valley (Table 62 in Appendix Section D.9). However, at Nephi, UT, Recovery forage yield was significantly lower than all other western wheatgrass cultivars except Arriba (Table 62 in Appendix D.9). Overall, these results suggest that Recovery will yield comparable or slightly less than other western wheatgrasses.

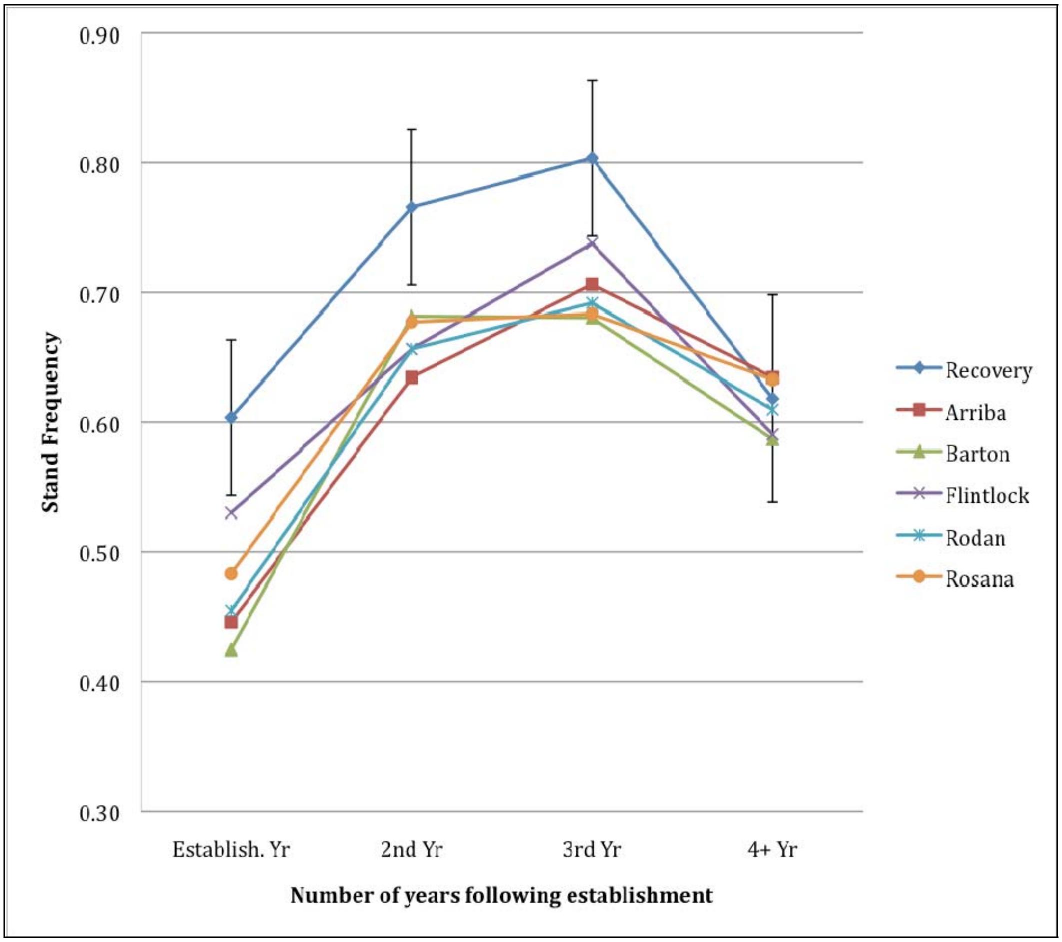

Figure 17. Stand of Recovery western wheatgrass as compared to standard western wheatgrass checks when evaluated at eight locations throughout the western United States Error bars are the LSD value at the P=0.05 probability level. The "4+ Yr" category is the latest evaluation taken at a given site and ranges from 4–6 years after planting. (Waldron et al. in press).

FirstStrike slender wheatgrass was selected for persistence and overall plant vigor in response to drought. It had significantly ($P<0.05$) more seedlings per unit area (m^2) than Pryor in the establishment year (Table 13, Table 29, and Table 30). For nursery sites at Fillmore, Utah, and Malta, Idaho, initial stand and persistence of FirstStrike were similar to the cultivar San Luis. FirstStrike was similar to or better than Pryor and San Luis for persistence. At Guernsey, Wyoming, dry matter yield was 27% greater ($P<0.07$) in FirstStrike than Pryor. FirstStrike germinated five days earlier than Pryor on three different soil types (sandy loam, loam, and sandy) than Pryor.

Table 29. Stand establishment and persistence over 1 year at two Fillmore, Utah sites, established fall 2003 (Site 1) and 2004 (Site 2) (Jensen et al. 2007).

Entry	Site 1 – % Stand Estab. 2004	Site 1 – % Stand Persistence 2005	Site 1 – % Stand Persistence comb. 2004-05	Site 2 – % Stand Estab. 2005
Siberian wheatgrass (Vavilov)				54
Siberian wheatgrass (Vavilov II)				79
Trailhead Basin wildrye				33
Snake River wheatgrass (Secar)	38	55	47	41
Snake River wheatgrass (SERDP Select)	64	68	66	58
Bluebunch wheatgrass (Goldar)	67	67	67	81
Bluebunch wheatgrass (P7)	60	66	63	48
Slender wheatgrass (Pryor)	34	44	39	50
Slender wheatgrass (San Luis)				87*
Slender wheatgrass (FirstStrike)	81*	90*	85*	78*
Western wheatgrass (Rosana)	73	90	81	57
Western wheatgrass (Flintlock)	84	83	84	—
Western wheatgrass (SB-2)	88	89	89	67
Western wheatgrass (Recovery)	49	74	69	62
LSD (0.05)	21	20	18	21

* FirstStrike was significantly better than the cultivar Pryor slender wheatgrass.

Table 30. Stand establishment at Malta, Idaho site, established fall 2004 (Jensen et al. 2007).

Entry	Establishment year 2005 (% Stand)
Siberian wheatgrass (Vavilov)	92
Siberian wheatgrass (Vavilov II)	95
Snake River wheatgrass (Secar)	79
Snake River wheatgrass (SERDP Select)	85
Bluebunch wheatgrass (Goldar)	79
Bluebunch wheatgrass (P7)	88
Slender wheatgrass (Pryor)	36
Slender wheatgrass (San Luis)	76
Slender wheatgrass (FirstStrike)	86*
Western wheatgrass (Rosana)	45
Western wheatgrass (Barton)	55
Western wheatgrass (SB-2)	68
Western wheatgrass (Recovery)	67#
LSD (0.05)	13

* FirstStrike was significantly better than the cultivar Pryor slender wheatgrass.
# Recovery was significantly better than the cultivar Rosana western wheatgrass

Vavilov II Siberian wheatgrass was selected for seedling and vegetative vigor, seed yield and early spring green-up. During the establishment year, Vavilov II Siberian wheatgrass had significantly ($P<0.05$) higher numbers of seedlings per unit area (m^2) than Vavilov at YTC (52 vs. 23%), Fillmore (79 vs. 54%), DPG (79 vs. 52%), and Curlew Valley (70 vs. 40%) (Figure 18; Tables 63-66 in Appendix D.9). In persistence after establishment, as measured by percent stand, Vavilov II was significantly more persistent than Vavilov at YTC (68 vs. 44%), Fillmore (84 vs. 62%), Curlew Valley (69 vs. 55%), and Malta (97 vs. 91%) (Figure 19; Tables 63-66 in Appendix D.9). Dry matter yields (64 cm x 38 cm plot) combined across YTC and Camp Guernsey were significantly ($P<0.05$) greater in Vavilov II (53 g $plot^{-1}$) than Vavilov (39 g $plot^{-1}$) (Table 67 in Appendix D.9).

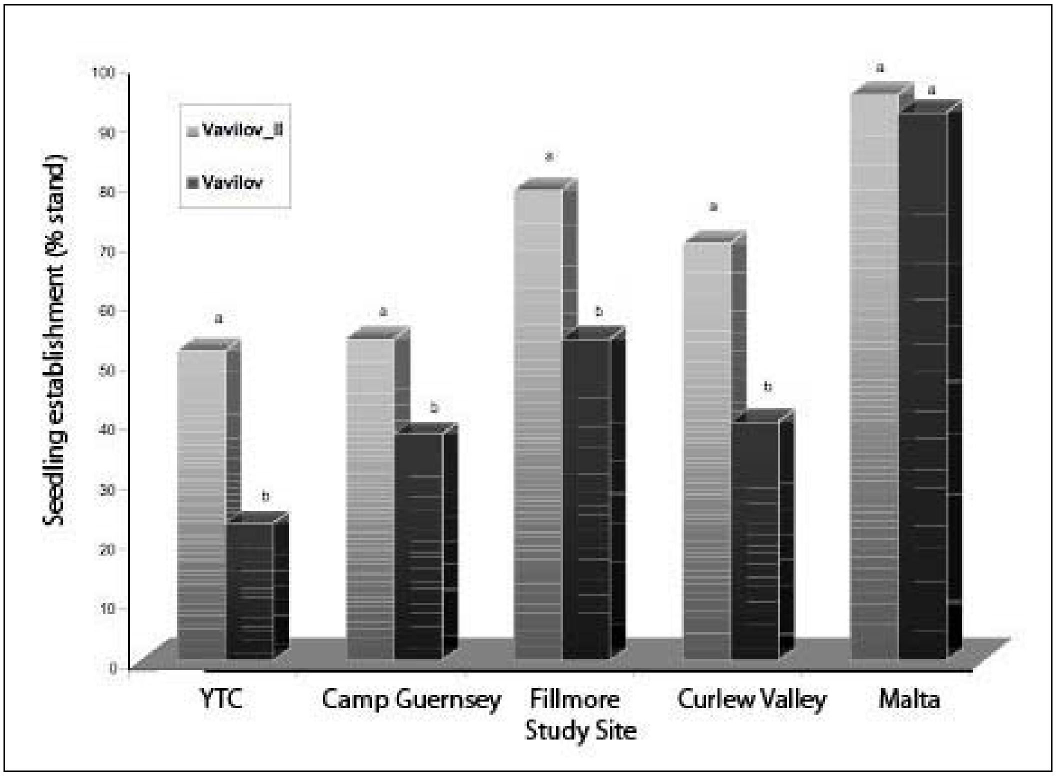

Figure 18. Seedling establishment for Vavilov II Siberian wheatgrass at five sites (Jensen et al. 2009).

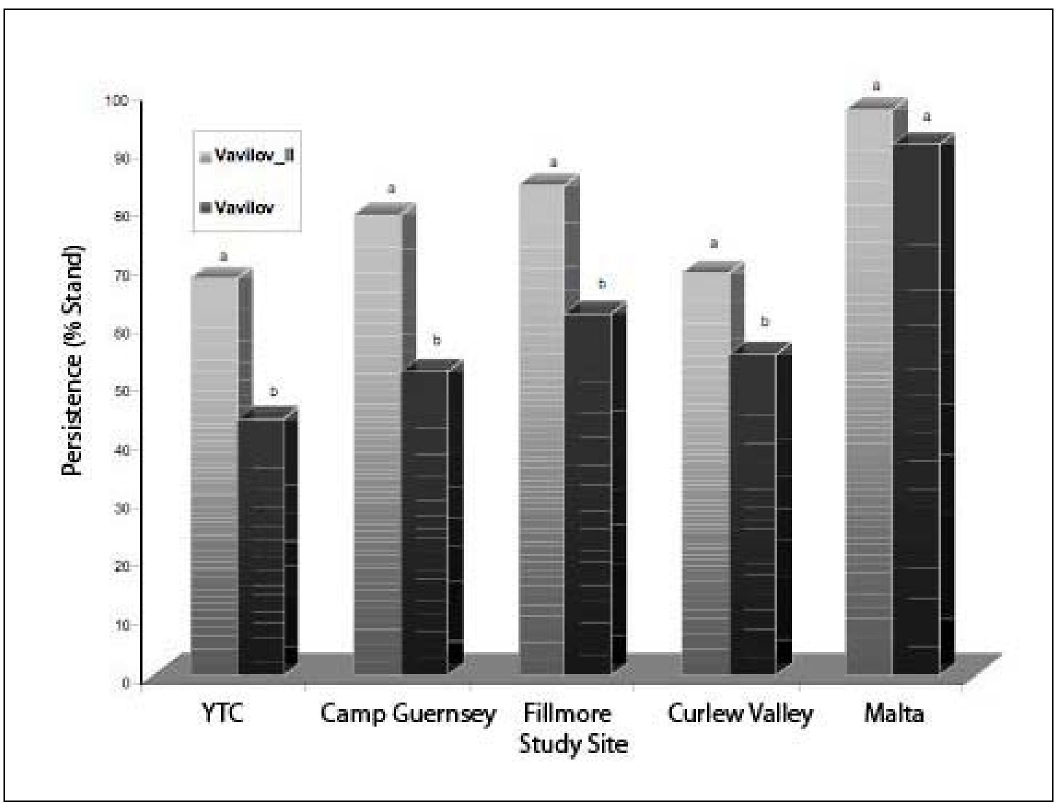

Figure 19. Persistence for Vavilov II Siberian wheatgrass at five sites (Jensen et al. 2009).

Bozoisky II Russian wildrye was selected for improved seed germination and seedling vigor. Bozoisky-II was evaluated in the Northern Plains Area (NPA) Regional Trials established in 1999 for initial stand, persistence, and dry matter forage production. Initial stands and persistence of Bozoisky-II were similar to Bozoisky-Select and Mankota combined over and within locations (Tables 68–70 in Appendix Section D.9). However, Bozoisky-II established significantly better and yielded greater than the tetraploid cultivar Tetracan and the tetraploid germplasm Tetra-1 (Jensen et al. 1998). Dry matter yields of Bozoisky-II, Bozoisky-Select, and Mankota were similar except at Green Canyon, UT, where Bozoisky-II had significantly greater ($P<0.05$) yield than Mankota (Table 71 in Appendix D.9).

6 Performance Assessment

The sections below discuss each performance objective previously shown in Table 4.

6.1 Improved establishment of modified germplasms

This objective was met for our four new cultivars. In field-spaced nursery trials, the cultivars Bozoisky-II Russian wildrye, FirstStrike slender wheatgrass, Recovery western wheatgrass, and Vavilov II Siberian wheatgrass had significantly ($P<0.05$) greater stand establishment than base population cultivar after one or more years as detailed below.

Recovery western wheatgrass was selected for seedling vigor and quick establishment under rangeland conditions. It was evaluated extensively at semiarid sites representative of different ecological regions in northern plains and western United States. Overall, it has shown superior and faster seedling establishment compared to commercially available cultivars Arriba, Barton, Flintlock, Rodan, and Rosana (Waldron et al. in press). Across locations, Recovery had higher frequency ($P \leq 0.05$) of plants than any other western wheatgrass cultivar until the fourth to sixth year after planting (see Figure 17). The rapid establishment of Recovery, in comparison to other western wheatgrass cultivars, will allow land managers to use this native grass species to help limit weed infestation and soil erosion in areas where the regularity of disturbances normally prevents western wheatgrass from becoming fully established (Waldron et al. in press).

Bozoisky-II Russian wildrye had significantly ($P \leq 0.05$) more seedlings per unit area than two other Russian wildrye germplasms in the study (Jensen et al. 2006) (see Tables 68-69 in Appendix Section D.9). Selection emphasis on Bozoisky-II was for increased seedling vigor during establishment.

During the establishment year, **Vavilov II Siberian wheatgrass** had significantly ($P<0.05$) higher numbers of seedlings per unit area at five locations (Tables 63-66 in Appendix Section D.9).

FirstStrike slender wheatgrass was selected for persistence and overall plant vigor in response to drought. Although selection emphasis was not on seedling establishment, it appears than an increase in seedling vigor was correlated with the selection for persistence and plant vigor under extremely dry conditions in this population. In seeded trials at four sites, FirstStrike had significantly ($P<0.05$) more seedlings per unit area (m^2) than did the cultivar Pryor slender wheatgrass in the establishment year (Tables 13, 29, 30). FirstStrike germinated five days earlier than Pryor on three different soil types (sandy loam, loam, and sandy) (Jensen et al. 2007) and at all but one temperature in growth pouch studies (Table 26).

6.2 Release of new germplasms

We met this objective by releasing six germplasms under the ESTCP program with a seventh currently in preparation. Four of those releases are cultivars and are discussed in the next section. Reliable Sandberg bluegrass and Yakima western yarrow were released as pre-variety germplasms (see Appendix C for a discussion of release types).

Yakima western yarrow was released as a source-identified class germplasm (Waldron et al. 2006b). The diversity within this germplasm is evident in the range of phenotypic differences found in the Generation G1 field. The field of G1 generation Yakima western yarrow showed excellent, vigorous growth in the nursery site at Cache County, Utah. Yakima was successfully established in a field trial at YTC, and an earlier western yarrow collection (1994) from the same 26 locations was tested at YTC, where it established and persisted much better than common variety-not-stated western yarrow. Yakima western yarrow is intended for use in rehabilitation and restoration of western rangelands. It should be particularly useful to help stabilize and add diversity to severely disturbed sites, such as military training lands and lands post wildfires.

Reliable Sandberg bluegrass was released as a selected-class germplasm (Waldron et al. 2006a). It was successfully established in several trials in Utah and Idaho and at YTC. Sandberg bluegrass is an important understory grass in the bluebunch wheatgrass–sagebrush ecological sites of the Intermountain and Northwest regions of the United States. It is a medium-lived, perennial bunchgrass valuable for soil erosion control, spring livestock and wildlife grazing, and biodiversity. It resists trampling and often is one of the first species to reestablish on sites disturbed by fire, large equipment and vehicles, and animals. Reliable's

intended use is for rehabilitation and restoration of western rangelands. It may be particularly useful as a pioneer plant species on severely disturbed sites, such as military training sites and after wildfires.

6.3 Release of new cultivars

We exceeded our goal of releasing two or more germplasms as cultivars under the ESTCP program. Four SERDP-select plant germplasms were released as cultivars with the potential for Plant Variety Protection (PVP) based on their breeding history and their response to selection for seedling vigor, persistence, and ability to regrow after disturbance. A minimum level of significance was set at alpha = 0.05, and SERDP-select materials were tested against these criteria. A fifth cultivar release of Snake River wheatgrass is possible in the next couple of years.

'Bozoisky-II' Russian wildrye was released in 2005 (Jensen et al. 2006). Bozoisky-II was selected for seedling vigor (emergence from a deep planting depth), seed mass, seed yield, vegetative vigor, total dry matter production, and response to drought. Bozoisky-II has a much broader genetic base than other Russian wildrye cultivars and has been evaluated extensively on rangeland sites in western United States. Seedling establishment of Bozoisky-II has been equal to or greater than commercially available cultivars. Within the Great Basin and Northern Great Plains, Bozoisky-II is adapted to sage-brush, mountain-brush, and pinyon-juniper on arid to semiarid rangelands. It is best adapted to loam and clay soils, although acceptable stands can be obtained on a wide range of soil types. Russian wildrye's resistance to drought exceeds that of crested wheatgrass (Asay and Jensen 1996).

'FirstStrike' slender wheatgrass was released in 2006 (Jensen et al. 2007). FirstStrike was selected for persistence and overall plant vigor in response to drought. FirstStrike is a multi-origin composite of four collections from Colorado and Wyoming and has been evaluated extensively on rangeland sites in western United States with seedling establishment equal to or better than commercially available cultivars.

'Vavilov II' Siberian wheatgrass was released in 2008 (Jensen et al. 2009). Vavilov II was developed for reseeding sandy soils on disturbed rangelands dominated by annual weeds as a result of severe disturbance, frequent fires, and soil erosion. Selection emphasis was on seedling establishment and plant persistence. The development of Vavilov II gives

land managers new plant materials with enhanced seedling establishment and persistence on dry harsh rangelands.

‘Recovery’ western wheatgrass was released in 2009 (Waldron et al. in press). Recovery was developed for reseeding rangelands following severe disturbance, frequent fires, and soil erosion. Selection emphasis in Recovery was on improved and faster seedling establishment. During the establishment year, Recovery had increased frequency of seedlings when averaged across eight locations than ‘Arriba’, ‘Barton’, ‘Flintlock’, ‘Rodan’, and ‘Rosana’ western wheatgrasses. Recovery continued to have superior stand until 4 to 6 years after planting, when due to their rhizomatous nature, all the western wheatgrasses were equal. Recovery is especially intended for revegetation of frequently disturbed rangelands, military training lands, and areas with repeated wildfires.

6.4 Improved resilience of modified germplasms to military traffic

Three of the SERDP-modified entries—Bozoisky II Russian wildrye, Vavilov II Siberian wheatgrass, and SERDP-select Snake River wheatgrass—did significantly ($P<0.05$) better than the commonly available varieties for all treatments. All entries, except for Pryor slender wheatgrass, had significantly less cover at the 4-pass treatment as compared to the 1-pass treatment. A large jump in soil moisture 1 year after tracking resulted in a higher overall plant cover, making it harder to discern what was happening as a result of the tracking.

6.5 Improved establishment of native grass stands

We studied the improved establishment rates of native plants using various mixed seedings at three locations (YTC, Camp Guernsey, Fort Drum). At all three locations in two climatic areas, we obtained native plant stands by combining native and introduced species together. Although there were few significant differences among the mixes, all of our mixes established significantly better ($P<0.05$) than the standard Guernsey mix at the Guernsey River site. At the Guernsey Tower site after 1 year, all mixes had significantly greater cover than the Guernsey mix, and the introduced-native mix 1 had significantly greater stand than the native only mix 2. At Fort Drum, we were able to obtain a stand of switchgrasses in 4 years.

6.6 Reduction of noxious weeds on training lands

Although we found no significant differences at YTC or Guernsey, the highest percentage of weeds were found with the all-native mix 2 and core native mix 4 at the Guernsey River site after 2 years. At Fort Drum, we did not test an all-native mix, but weed percentages were very low in all introduced-native mixes except the weeping lovegrass-hairgrass mixture after 4 years; the native hairgrass was not successful in any mixture and the weeping lovegrass had died back after 4 years allowing undesired species to move in.

In earlier work at Fort Carson, which we used for our cost assessment analysis, we also showed reduction in weed stands across all our mixtures after 3 years (see Figure 3).

6.7 Qualitative results

6.7.1 Reliability

We have shown the reliability of the modified germplasms with successful plantings at four facilities in two climatic areas. Across all studies, the germplasms were able to establish and grow within the 4-year time frame of this demonstration. The germplasms were able to survive under various settings including military vehicle tracking and different climatic regimes.

6.7.2 Ease of use

All seedings were completed with conventional no-till seeding equipment, which is a one-pass procedure in wide use at military facilities. The modified germplasms and ecological-bridge mixtures require no additional equipment, labor, or skills.

6.7.3 Versatility

As noted above, we have demonstrated successful and improved performance in a variety of locations under different conditions.

6.7.4 Maintenance

No maintenance is required.

6.7.5 Availability of seed

Because there is no significant increase in cost to use our modified plants or seeding methods, the only barrier to implementation of the technology would be the cost and availability of seeds of the modified varieties. One of our goals was to convince producers to grow the seed in large enough quantities to make their prices comparable to those already on the market.

We entered into a contract with the USDA Natural Resources Conservation Service (USDA-NRCS) Plant Material Center in Aberdeen, Idaho, to produce seed of new SERDP select germplasms of three species. About 5,200 pounds of seed were produced for distribution to military facilities in FY07, and a comparable amount of seed was produced in FY08. The seed was distributed to YTC, Mountain Home Air Force Base (Idaho), Fort Carson, Camp Williams (Utah), Camp Guernsey, and Fort Riley (Kansas). Our first sale of seed to a commercial producer was completed in 2007. The producers purchased 300 lb of FirstStrike slender wheatgrass foundation seed that will result in 36,000 lb of seed for sale at a value of $270,000.

The seeds for many of these germplasms should be available for some time; additional growers are producing seeds for retail sale, and the USDA-NRCS is recommending some of these germplasms for seeding to restore lands.

6.7.6 Awareness of seed capabilities and planting methods

To help market the new germplasms, we prepared two white papers describing the release of the new germplasms and their potential vulnerability and resistance to invasive species: "Decision Paper on Public Releases for the Germplasms Developed under the SERDP and ESTCP Programs" (see Appendix B) and "Implementation and Commercialization of New Germplasms for Use on Military Ranges."

The demonstration studies conducted during this program were made available for inspection by land managers in the Intermountain West and Northeast United States climatic regions. We also gave presentations about our modified germplasms and ecological-bridge mixtures at several military facilities and at professional and military-related meetings.

We partnered with the Army Environmental Command (AEC) to prepare a planting guide for selecting appropriate ecological-bridge seed mixtures (Palazzo et al. 2009). We are currently expanding our geographic area by promoting the ecological-bridge concept to military bases in Hawaii and the Southeastern United States.

7 Cost Assessment

This cost assessment is based primarily on work performed earlier at Fort Carson. Those results are summarized in Section 2.2.

7.1 Cost model

The Environmental Cost Analysis Methodology (ECAM) tool is designed to facilitate the gathering and analyzing of economic data in a manner that will allow for more accurate evaluation of investment in pollution prevention technologies. Our project did not involve hazardous waste materials, and, as such, we do not meet the criteria for environmental reporting requirements and we did not use the ECAM tool.

In our project, we used equipment that is similar to or the same as equipment that is already in place at the facilities in the project's application. In this case, the cost difference is minimal in the proposed process as compared to the one currently used at the sites. The only minor increased cost we can envision may be in the increased cost to purchase the new seeds initially. With greater demand, the cost of the seeds should decrease and be comparable to those currently on the market, which should ultimately lead to reduced overall costs. Table 31 summarizes the costs related to revegetation with our modified germplasms and ecological-bridge mixtures. Section 7.3 includes information on costs related to current revegetation practices.

Table 31. Cost model for seeding modified germplasms or ecological-bridge mixtures.

Cost element	Data tracked during the demonstration	Estimated costs
Seed costs	Modified germplasms, new cultivars	Possible increase in seed costs for new germplasms and cultivars
Installation costs	Labor, equipment, and chemicals needed to seed	No change from normal operations
Operation costs	None necessary	None
Monitoring costs	None necessary	None
Maintenance	Reseeding requirements	No or reduced need to reseed

7.2 Cost drivers

No new equipment, skills, health and safety requirements, or regulatory standards are needed to use the new germplasms or seeding methods. Existing equipment and no-till seeding methods can be employed to seed the new varieties and mixtures. The key to "implementation" of this methodology is the proper decision making for selecting appropriate revegetation materials. We prepared a planting guide (Palazzo et al. 2009) that includes detailed information on plant selection for specific microclimatic ranges, training scenarios, and locations for optimal uses for each improved germplasm, as well as guidelines for selecting appropriate ecological bridge seed mixes.

The factors affecting cost and performance are the availability and cost of the improved germplasms and cultivars, and the cost savings resulting from improved performance of the vegetation. Currently available planting equipment and skills are used with the new materials. The only differences are which types of seeds or mixtures of seeds are planted. The seeds for the new plant materials are unlikely to differ greatly in cost from currently used cultivars.

Potential cost savings can be realized from (a) the ability to seed less frequently because of increased establishment rates and better wear resiliency, (b) a decrease in the need to consider other methods of controlling invasive weeds, and (c) the reduced downtime on ranges which should lead to cost efficiencies in scheduling training programs.

Using native plant species over introduced plant species can increase seed costs significantly because the native species are not as widely used. However, the actual land preparation and seeding practices should remain the same with our modified germplasms and recommended mixtures, and the frequency should be reduced for reseeding operations and the amount of chemical or mechanical control of noxious weeds.

7.3 Cost analysis and comparison

We provided a cost estimate for one example of cost savings at Fort Carson that considers the greater resilience of the new germplasms and the faster establishment rates of native plants using the ecological-bridge mixtures (Table 32). However, it is difficult to obtain a cost comparison since our results provide choices to military land managers who have an array of

considerations in obtaining a vegetative cover on military lands. Those considerations include the intensity of land use, the choice of native or introduced plants, and the degree of encroachment by noxious weeds. Each consideration requires different seed selections, as described in our planting guide (Palazzo et al. 2009).

We conducted one of our early tests on ecological-bridge seed mixtures at Fort Carson, comparing several test mixtures with the standard Fort Carson mix (Palazzo et al. 2003; see also Section 2.2 of this report). At the same time, we looked into current seeding practices on that facility because it is a good candidate for using the new germplasms and seed mixtures.

Land rehabilitation at Fort Carson currently involves an average of 4,000 acres annually, for an annual cost of $260,000 (based on $65 per acre cost). The time required between reseedings is based on land use. Intensely used areas need to be seeded annually, and those with little or no use will probably never need reseeding. Moderately used lands are generally reseeded every 3–5 years, with an average of every 4 years. We believe that using our modified germplasms and new cultivars in the mixtures can conservatively extend the use of moderately used areas by at least 2 years; in other words, such areas would generally require reseeding every 6 years. The tables below show some calculations for cost savings based on the frequency of seeding those moderately used land areas.

Table 32 shows the average annual cost of seeding an acre of moderately used lands to control soil erosion assuming a 4-year cycle for existing germplasms and a 6-year cycle for SERDP-modified germplasms. Depending on seed cost, there will be a savings of 28%–33%.

Table 32. Approximate costs of seeding moderately used lands at Fort Carson.

	Existing germplasms	New germplasms at same seed cost	New germplasms with 20% increase in seed cost
Seeding cost per acre	$65	$65	$70
Average time between reseedings	4 years	6 years	6 years
Average annual seeding cost per acre of moderately used land (cost per acre / years between seedings)	$16.25	$10.83	$11.67
Average annual seeding savings per acre of moderately used land	—	$5.42	$4.58
Annual savings		33%	28%

Although the number of moderately used acres to be sown changes annually, it usually is about 2,000 acres at Fort Carson, accounting for about half of the estimated $260,000 annual cost of land rehabilitation, or $130,000 per year. If we multiply that annual seeding cost ($130,000 per year) by the percent of annual savings (33% or 28%) as shown above, we produce a net savings of $42,900 or $36,400 per year.

8 Implementation Issues

The end-users for the modified plant germplasms and seeding methods are land managers on military and other federal lands. They need to know that our seeds and planting methods will produce improved, low-maintenance results on their lands, and sufficient seeds must be available to them at a cost equal to or less than currently available plant materials. The seeds themselves may be used over a wide geographic area (see Figure 6); the only "customization" required is selection of appropriate species for use at individual facilities in terms of soil type, land use, climate, and types of plants desired (native and/or introduced species).

The demonstrations described in this report should provide land managers with ample justification to use our new plant materials and suggested mixtures. Throughout the project, our demonstration plots at two military installations have been open to land managers to increase awareness and promote transfer of the technology. We have consulted, and will continue to consult, with military land managers at numerous sites by phone and in person. We have presented our findings at conferences, workshops, and other appropriate forums, such as ITAM meetings (Palazzo et al. 2006, 2007) and the Battelle Conference on Sustainable Range Management in New Orleans (January 2004). As appropriate or when requested, we will distribute copies of the official germplasm release notices along with our existing reports on our spring 2002 workshop on the modified germplasms (Hardy and Palazzo 2002), our final SERDP report (Palazzo et al. 2003), this report, and the Planting Guide (Palazzo et al. 2009).

The Planting Guide (ibid.) that we produced as part of this demonstration project provides the necessary information on the use of the modified germplasms with other compatible species in seeding mixtures, planting recommendations, and criteria to select appropriate ecological-bridge methods. The planting guide includes sections on land use in the western United States, along with detailed information on individual species. Each land use intensity and eco-region section gives suggestions for appropriate species and mixes for various training-land uses and vegetation goals. Users may then refer to the detailed species section for information on planting.

We decided to go through a public release of the seed as opposed to a private release. The advantages to a public release are that foundation seed used to produce seed commercially will be available to all growers, and the greater distribution should lower the cost of the seed. The disadvantage to the public release is that poor quality seed may be produced and hurt the reputation of the new germplasm. Also, since many growers have the new germplasm, some may be a reluctant to market the seed. We hope to overcome this by working with seed producers.

We made seed available to military land managers for demonstration purposes. Initially, we contracted with the USDA-NRCS Plant Material Center in Aberdeen, Idaho, to produce sufficient seed for selected military facilities at no cost; seed was distributed in FY07 and FY08. As the germplasms continue to prove themselves and the demand for the seed becomes known, we anticipate that commercial seed producers will be more interested in carrying the seeds for sale. Also, to support the use of our new germplasms, the USDA-NRCS has acknowledged the improved performance of our species by including several our germplasms on their recommended list that retail seed buyers use to select cultivars of various grass species. At this time, only SERDP FirstStrike Slender wheatgrass is available for commercial sale, and it was recently included in a Fort Carlson seed purchase of $30,000.

Other military involvement related to this program:

- The results of the ecological-bridge research have been used for the last 8 years at Fort Drum to more effectively establish native plants on sandy soils. Our tests showed that the seed mixture allowed the military to use the land again in less time. In 2009, we held a meeting at Fort Drum to demonstrate this concept. Invited participants included people from Camp Ripley, Minnesota; Fort Bragg, North Carolina; Fort Indiantown Gap, Pennsylvania, and the AEC.

- Yakima Training Center has been using the seeding recommendations provided for the past 2–3 years with good results, and their plan is to include other recommendations as they become available. Their direct claim is:

> One of the most important aspects that has helped us has been the work you have done with improvement

of the native species. In fact, we have developed some aggressive erosion control projects (stream bank sloping projects similar to what Jeff has done at Carson) for implementation this spring and summer that includes use of some of these native species for revegetation efforts. Having these species become available was a major factor in our decision to carry out this aggressive bank sloping effort because we knew revegetation would actually be the key to overall success. Without these species, the project would be dead on arrival at Yakima.

- Yakima Training Center is also using our methods to reseed upland areas following disturbance. Both the Record of Decisions (RODs) for the YTC Expansion and the Fort Lewis Stationing actions include requirements for continued upland reseeding of up to 4,000 acres annually to mitigate impacts associated with erosion, surface water quality, and noxious weeds. These mitigation requirements are direct benefactors of this ongoing research effort to develop the various cultivars.

- Recently we have expanded the ecological bridge concept to military facilities in the Southeastern United States and Hawaii.

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Appendix A: Points of Contact

Point of Contact	Organization	Phone / Fax / email	Role in Project
Antonio J. Palazzo	ERDC-CRREL 72 Lyme Road Hanover, NH 03755-1290	603-646-4374 Fax: 603-646-4785 Antonio.J.Palazzo@usace.army.mil	Lead PI, project implementation and coordination, establishment studies, cultivar releases
Timothy J. Cary	ERDC-CRREL 72 Lyme Road Hanover, NH 03755-1290	603-646-4358 Fax: 603-646-4785 Timothy.J.Cary@usace.army.mil	Establishment studies, plot monitoring
Kevin B. Jensen	USDA-ARS Forage and Range Research Lab 695 North 1100 East Utah State University Logan, UT 84322-6300	435-797-3099 Fax: 435-797-3075 kevin.jensen@ars.usda.gov	Plant-breeding, establishment studies, cultivar releases
Dick Gebhart	ERDC-CERL 2902 Newmark Drive Champaign IL 61822-1076	217-352-6511, x5847 Fax: 217-373-7222 Dick.L.Gebhart@usace.army.mil	Data analysis
Larry Holzworth (retired)	USDA-NRCS. Federal Bldg, Rm 443 10 East Babcock St Bozeman, MT 59715-4704		Monitoring demonstration plots
Susan Hardy (retired)	ERDC-CRREL 72 Lyme Road Hanover, NH 03755		Project planning, documentation
Janet Clark	Center for Invasive Plant Management (CIPM) Montana State University P.O. Box 173120 Bozeman, MT 59717	(406) 994-6832 Fax: (406) 994-1889 cipm@montana.edu	Promoting the ecological bridge concept
Dustin Kafka	Wyoming NGB 5500 Bishop Blvd. Cheyenne WY 82001-3320	(307) 836-7785 dustin.kafka@us.army.mil	Monitoring demonstration plots
Peter Nissen	Directorate of Environment and Natural Resources ATTN: Pete Nissen Building 810 Yakima Training Center Yakima, WA 98901	(509) 577-3500 Fax: (509) 577-3336 peter.nissen@us.army.mil	Site sponsor (YTC)

Appendix B: Decision Paper on Public Releases for the Germplasms Developed under the SERDP and ESTCP Programs

Authors: Antonio J. Palazzo, Kevin B. Jensen, and Susan E. Hardy

B.1 Introduction

The objective of this white paper is to provide a rationale for our choice of public releases as the most cost-effective and efficient method to get our plants in use on military lands. The germplasms were developed mainly under the SERDP/ESTCP programs during the last 8 years. Under the SERDP project SI-1103, we conducted basic and applied research to develop plant germplasms more resilient to military training activities. Under ESTCP project SI-0401, we are demonstrating the resiliency of these germplasms either alone or in mixtures on military lands.

B.2 Project summary

We bred native and introduced plant species with modified traits related to resiliency and establishment on military lands. Our improved plant materials are ecologically compatible to military sites because they were developed on and from collections of species native to or previously seeded at these sites. We have published widely on various topics related to the concepts and methods, genetics, releases, and performance and resiliency of the species. Our studies on "ecological bridges" confirm that we can select seed mixtures that will establish more rapidly than all-native mixes, allow earlier land use for training, and ultimately lead to healthy and persistent stands of native plants. The species in the seed mixtures and the equipment needed are readily available and the seeding can be done in one application, thus saving money. Our modified germplasms will make these seeding mixes even more desirable.

The overall objectives of the projects were to:

- breed modified native and introduced plant germplasms that have increased persistence and establishment characteristics under military training activities;

- understand the effects of training on soil compaction, plant injury, and regrowth;
- evaluate seeding methodology to better establish native and non-invasive non-native grasses in mixed stands while promoting resistance to invasion by non-native invasive plants.

B.3 Business plan

In 2002, we prepared a business plan describing our efforts to transfer this technology to commercial seed development so that the new plant materials and associated seeding methods may be readily available to military and other federal land managers. Our technology-transfer approach includes (1) demonstrating the advantage of the new germplasms and (2) developing a seed market for dispersal. To meet the **demonstration** objective, we established and monitored demonstration plots at selected installations to show the benefits of these new germplasms to private and public land managers, users, and seed producers. For **marketing**, we have been giving presentations relating to plant establishment, management, and ecological parameters of the new germplasms.

B.4 Marketing

Our marketing efforts for all the new germplasms are aimed at creating and promoting demand to show seed producers that it is commercially viable to produce the seed of these species. We have promoted the important beneficial characteristics of the species to military lands managers in the field, command managers, Army Environmental Center (AEC), and other managerial types. To produce even more demand, we have also discussed the use of these with the Bureau of Land Management (BLM) and other federal agencies that purchase large quantities of seed. We have visited a seed production company and made a presentation to the National Seed Producers Association as well as at numerous professional meetings.

We anticipate that our work will provide a better return on the military investment. Within the range of distributions for the new germplasms, we have identified 42 DoD facilities, which include over 525,000 hectares (1.3 million acres) of Army and Air Force land. The new germplasms are also appropriate for other federal, state, or local agencies; highway rights-of-way; mine spoils; rangelands; and other disturbed areas.

B.5 Seed production

In 2002 we contracted with the USDA-NRCS in Aberdeen, Idaho, to produce seed of three SERDP-developed species: western wheatgrass, slender wheatgrass, and Siberian wheatgrass. (The initial seed production of approximately 2,000 lb was distributed free to selected military installations in February 2007 after this white paper was written.)

B.6 Release process

All plant releases adhere to requirements set forth for publicly or privately released plant materials under a Plant Variety Protection (PVP) agreement according to USDA-ARS and CRREL protocol. We proposed that the seed be formally released in joint ownership with USDA-ARS and Army (CRREL) with appropriate recognition given to SERDP for providing partial financial support in the development of these plant materials (see release notice write-up). Foundation seed will be produced and maintained by the USDA-ARS-Forage and Range Research Lab and made available to the public for certified seed production through the Utah Crop Improvement Association.

B.7 Private vs. public release

A major question now that the germplasms are close to being used in the field is to determine if they should be released publicly or privately. There are benefits and detriments with each method. The major benefit to a public release is that certified seed can be produced by any private seed grower without licensing. Directly related to the rapid acceptance of new revegetation (dryland) grasses on the market is the ability to have large amounts of seed available at the time of official release. The major drawback to a public release is the lack of advertising by one company trying to market the material. However, we do not feel that this alone justifies a private (licensed) release of this material. A private release might produce royalties for seed sales to non-government entities and it would allow us to control which seed companies receive the license to grow the seed, but that does not guarantee that the company will actually ever grow the seed for sale. Most seed produced through private-release government contracts is for use in limited areas. Seed producers are not accustomed to producing seed for the general market under government contracts. The amount of seed to be sold to the military is small compared to the entire market. There are greater sales potential for seed produced

for grazing lands and reseeding after fires, and our new germplasms could be very useful for these demands. A public release appears to be the best method of insuring that our cultivars are produced and available for the widest possible market.

B.8 Conclusions

Regardless of whether seed is released publicly or privately, we can control the quality of the seed by requiring that only certified seed be produced via PVP protection. In considering all factors, it would be most cost-effective to the military, government, and private users to release these plant materials (cultivars only) publicly with PVP protection to ensure that only certified seed be sold on the market. Foundation seed for the production of certified seed can be obtained through Utah Crop Improvement Association.

Appendix C: Germplasm Release Types and Requirements

Early in the ESTCP project, we prepared a white paper (reprinted in Appendix B) describing the reasons for the various releases of the SERDP-select germplasms as a cultivar, source identified, selected, or tested class of germplasm. The conclusions of the white paper were:

> Regardless of whether seed is released publicly or privately, we can control the quality of the seed by requiring that only certified seed be produced via PVP protection. In considering all factors, it would be most cost-effective to the military, government, and private users to release these plant materials (cultivars only) publicly with PVP protection to ensure that only certified seed be sold on the market. Foundation seed for the production of certified seed can be obtained through Utah Crop Improvement Association.

Under the ESTCP program, four SERDP-select plant germplasms were released as cultivars with potential for Plant Variety Protection (PVP), based on their breeding history and their response to selection for seedling vigor, persistence, and ability to regrow after disturbance (two cultivars were released earlier under our SERDP funding). A minimum level of significance was set at alpha = 0.05, and SERDP-select materials were tested against these criteria.

Pre-variety germplasms require less (or no) testing to justify release. Pre-variety germplasm categories (AOSCA 2003) are:

- **Source-identified class**: an unevaluated germplasm, identified only as to species and location of the wild growing parents.
- **Selected class:** germplasm shows promise of desirable traits, having been selected either within or as a common site comparison among accessions or populations of the same species.
- **Tested class**: germplasm for which progeny testing has proven desirable traits to be heritable.

Progeny testing data for **cultivar** release must encompass two locations (environments) or 2 years of data. Additionally, an application for PVP Certificate (USDA form GR-470, available at [accessed June 2009] www.ams.usda.gov/science/pvpo/Forms/forms.htm) must include:

Exhibit A. Breeding history. To include the following:

1. A full disclosure of the genealogy back to publicly known varieties, lines, or clones, including the breeding method;
2. The details of subsequent stages of selection and multiplication used to develop the variety;
3. A statement of uniformity reporting the level of variability in any characteristics of the variety (commercially acceptable variability is allowed);
4. A statement of genetic stability showing the number of cycles of seed reproduction for which the variety has remained unchanged in all distinguishing characteristics; and
5. The type and frequency of variants observed during reproduction and multiplication.

Exhibit B. Statement of distinctiveness. This must clearly state how the application variety may be distinguished from other varieties of the same species. It must:

1. Identify the most similar variety or group of varieties and state all differences objectively;
2. Attach statistical data for characters expressed numerically and demonstrate that these are clear differences; and
3. Submit, if helpful, seed and plant specimens or photographs (prints) of seed and plant comparisons that clearly indicate distinctness.

Exhibit C. Objective description of the variety. For example, resistance to disease, establishment rate, and plant persistence.

Exhibit D. Optional supporting information. The applicant may provide additional information, specimens, and/or materials in support of the claims of the application.

Exhibit E. Statement of basis of ownership.

The general chronology for the release of a germplasm or cultivar is that a release notice, including release type and all supporting data, is first prepared for approval by the agency or agencies developing the plant material (in this case, ERDC-CRREL and the USDA-ARS). After their approval, the release notice is brought before either the AOSCA or State Certification Board to get the material into the seed certification program. After approval of each release, an article is submitted to *Crop Science* or the *Journal of Plant Registrations* to announce the release.

Preliminary decisions about the appropriate release type for each SERDP-select population of plants as a cultivar or germplasm were based on breeding history, the unique differences observed in these plants in the later generations in the breeding process, and the potential demand in the marketplace. As we developed the plants, we adjusted release decisions for any and all germplasms based on the physiological and genetic data collected. We released the SERDP-select germplasms of western wheatgrass, slender wheatgrass, Russian wildrye, and Siberian wheatgrass as cultivars, with release notices in 2006 through 2009; the final PVP application process is usually completed within 2 years. Because they are broad-based collections with little or no selective breeding applied, the Sandberg bluegrass and yarrow germplasms were released as either source-identified or selected-class pre-variety germplasms in 2004 or 2005. We used this demonstration program to advance our remaining germplasms as far as possible toward release as cultivars.

Appendix D: Data

This appendix contains additional data or more detailed data than are shown in the bulk of this report.

D.1 Results of preliminary evaluation trials to identify promising species (1994–1996)

At the beginning of the SERDP program, many more species were examined and eventually dropped (based on adaptive characteristics) as the most promising species became apparent. We began with evaluation trials at two U.S. Army sites to help identify promising germplasms. The evaluation trials to assess stand establishment were conducted at Fort Carson in south-central Colorado and at the Yakima Training Center (YTC) in south-central Washington. The trials were established during the fall of 1994 and 1996. The seeded evaluation sites at the facilities differed in soil type and precipitation, which allowed for evaluation of germplasms over different environmental regimes (Table 33).

Table 33. Precipitation and soil types at species-evaluation sites.

Location	Site	Annual precipitation	Soil type
Yakima, Washington	Snake A and B	200-250 m	Benwy series
Fort Carson, Colorado	Turkey Creek	300-350 mm	Rizozo-Neville Complex
	South Boundary	175 –225 mm	Minnequa-Manvel loams

Two evaluation trials were conducted at Fort Carson: Turkey Creek (TC) and South Boundary (SB). The soils at SB are shallower, much drier, and less fertile than those at the TC site. Both sites received less than normal precipitation during our trials, especially in the latter years. The following two tables show the stand establishment results over successive years (Table 34 and Table 35).

Table 34. Stand establishment of perennial grasses at Fort Carson Turkey Creek Site, seeded fall 1994.

Entry	Mean % stand				
	1997	1998	1999	2000	2001
Introduced entries:					
Crested wheatgrass					
CD-II crested wheatgrass	100	97	94	89	99
RoadCrest crested wheatgrass	91	100	100	92	93
Siberian wheatgrass					
P27 Siberian wheatgrass	84	100	94	91	90
Vavilov Siberian wheatgrass	83	97	88	80	95
Kazakhstan Siberian wheatgrass	73	94	78	69	83
Russian wildrye					
Tetraploid Russian wildrye	68	94	91	78	93
Mankota Russian wildrye	46	91	88	72	89
Bozoisky Russian wildrye	30	84	81	64	86
Native entries:					
Thickspike wheatgrass					
Sodar thickspike wheatgrass	55	91	84	80	93
E27 thickspike wheatgrass	52	81	75	66	77
Indian ricegrass					
Paloma Indian ricegrass	31	56	47	30	28
T593 Indian ricegrass	13	38	31	19	28
Nezpar Indian ricegrass	26	25	19	23	12
CSU10 Indian ricegrass	9	22	16	16	25
Miscellaneous species					
Rosana western wheatgrass	54	81	100	97	100
Needle and thread grass	5	31	47	45	51
Alma blue grama	0	0	31	22	15
Vaughan sideoats grama	0	0	19	19	15
LSD (0.05) entries	8	16	18	16	14

Table 35. Mean percent stand of native and introduced grasses at Fort Carson South Boundary, seeded fall 1996.

Entry	Mean % stand				
	1997	1998	1999	2000	2001
Introduced entries:					
Russian wildrye					
Bozoisky	63	93	94	81	91
Tetraploid	59	88	78	70	88
Syn A	66	88	84	78	86
Mankota	72	78	88	80	85
Crested wheatgrass					
CD-II	69	41	47	37	30
RoadCrest	88	94	91	83	91
Siberian wheatgrass					
Vavilov	81	81	78	64	78
Kazak	56	69	63	52	55
Intermediate wheatgrass					
Luna	28	9	16	7	3
Rush	34	6	13	1	1
Native entries:					
Western wheatgrass					
Barton	63	50	72	69	88
Rodan	63	44	53	42	58
Rosana	41	34	53	50	78
Thickspike wheatgrass					
E-27	25	3.	6	3	4
Sodar	28	13	3	8	14
Miscellaneous species					
Pryor slender wheatgrass	72	38	31	7	0
Bottlebrush squirreltail	34	6	3	4	2
Sandhollow	25	9	9	4	3
Sand lovegrass	31	3	16	0	0
Overall mean	53	45	47	39	44
LSD (0.05)	18	23	20	15	18

At YTC, evaluation trials were conducted on adjacent Snake River sites A and B. The YTC location received 353, 375, 175, and 193 mm in 1995, 1996, 1997, and 1998, respectively. Results are shown in the next two tables Table 36 and Table 37.

Table 36. Seeding vigor ratings and percent stand of native and introduced perennial Triticeae grasses during stand establishment (1995) and subsequent years on Snake A site at Yakima Training Center.

Entry	Seedling vigor [z] May 1995	% Stand [y] 1995	% Stand 1996	% Stand 1997	% Stand 1998
Snake A Introduced Entries					
Siberian wheatgrass					
Vavilov Siberian wheatgrass [T]	9	99	100	100	100
P-27 Siberian wheatgrass [T]	9	96	82	83	88
Kazak Siberian wheatgrass [T]	7	75	66	80	72
Mean	8	90	83	88	87
Crested wheatgrass					
Hycrest [T]	7	94	82	69	79
Ephraim [T]	8	77	69	71	75
Mean	7	85	75	70	77
Russian wildrye					
Bozoisky [T]	5	67	57	55	63
Tetraploid [T]	4	50	25	38	38
Mean	4	59	41	46	50
Intermediate wheatgrass (cv. Luna) [T]	4	61	72	77	78
Snake A Native Entries					
Wildryes [)]					
Leymus-1 hybrid	1	8	0	3	7
Basin wildrye (Yakima) [T]	3	35	13	34	38
Mean	1	21	7	19	22
Bluegrasses					
Canby bluegrass [T]	8	69	70	60	82
Sandberg bluegrass	7	49	50	51	54
Mean	7	59	53	32	68
Indian ricegrass					
Nezpar Indian ricegrass	6	60	10	0	10
T553 Indian ricegrass	1	11	3	0	16
Mean	3	35	7	0	13
Western wheatgrass (cv. Rosana) [T]	3	33	35	32	41
Bottlebrush					
Squirrel tail 87	3	41	41	0	0
Squirrel tail 89	6	55	47	0	0
Mean	4	48	44	0	0
Miscellaneous species					
Needle and thread grass	2	14	0	8	6
SL hybrid (thickspike X bluebunch)	4	46	57	34	50
Mean	2	30	28	21	28
LSD (0.05)–Entries	1	19	14	12	14
LSD (0.05)–Species	2	20	18	17	17

[z] Seedling vigor ratings 9 May 1995, following a dormant fall seeding in 1994; 1=poor, 9=best seedling vigor.

[y] Percent stand based on visual ratings.

[T] Entries included in the tracking study

Table 37. Seeding vigor ratings and percent stand of native and introduced perennial Triticeae grasses during stand establishment (1995) and subsequent years on Snake B site at Yakima Training Center.

Snake B Native Entries	Seedling vigor [z] May 1995	% Stand 1995	% Stand 1996	% Stand 1997	% Stand 1998
Bluebunch wheatgrass					
Goldar [T]	7.0	67	56	49	75
Whitmar [T]	6.3	66	72	62	75
ACC-238 [T]	6.0	70	53	53	75
Yakima collection [T]	6.5	59	38	45	69
Mean	6.4	66	55	52	73
Snake River wheatgrass					
Secar [T]	7.3	69	94	92	97
ACC-707 [T]	7.0	75	88	75	91
EVT-572 [T]	7.5	73	91	87	100
Mean	7.3	72	91	85	96
Thickspike wheatgrass and hybrids					
Bannock [T]	7.3	73	72	53	75
Sodar	6.5	64	41	35	41
E-20 (thickspike X Snake River) [T]	7.0	72	78	80	88
E-27 (thickspike X Snake River) [T]	6.5	70	81	69	81
SL hybrid (thickspike X bluebunch)	4.3	52	22	23	28
Mean	6.3	66	59	52	63
LSD (0.05)–Entries	1	14	16	11	10
LSD (0.05)–Species	0.6	8	15	12	13

[z] Seedling vigor ratings 9 May 1995, following a dormant fall seeding in 1994; 1=poor, 9=best seedling vigor.

[y] Percent stand based on visual ratings.

[T] Entries included in the tracking study

D.2 Yakima Training Center seeding list (monocultures and mixtures)

The site Exit 11 site at Yakima Training Center was seeded on 21-22 October 2002 (Table 38). Plots are 1.5 x 24 m (5 x 80 ft) with six rows at 2.5 cm (10 in.) apart. Seeds were placed 1.25–2.0 cm below the soil surface at a rate of approximately one seed/cm (2.5 seeds per linear inch). Plots were arranged in randomized complete blocks with four replications.

There were 9-m wide borders of Hycrest crested wheatgrass between replications. Plots were oriented east to west.

Table 38. YTC Exit 11 monoculture and mixture seeding list (21-22 October 2002).

Plot	Entry	Rep
10	BBWG-SERDP	1
16	BBWG-SERDP	2
9	BBWG-SERDP	3
11	BBWG-SERDP	4
5	BOZXTET	1
12	BOZXTET	2
15	BOZXTET	3
3	BOZXTET	4
9	GOLDAR	1
10	GOLDAR	2
8	GOLDAR	3
14	GOLDAR	4
19	MIX-1	1
4	MIX-1	2
17	MIX-1	3
20	MIX-2	1
2	MIX-2	2
7	MIX-2	3
10	MIX-2	4
11	PRYOR	1
20	PRYOR	2
19	PRYOR	3
16	PRYOR	4
3	ROADCREST	1
5	ROADCREST	2
2	ROADCREST	3
2	ROADCREST	4
13	ROSANA	1
17	ROSANA	2
11	ROSANA	3
19	ROSANA	4
16	SAND-SERDP	1
11	SAND-SERDP	2
14	SAND-SERDP	3

Plot	Entry	Rep
7	SECAR	1
7	SECAR	2
1	SECAR	3
18	SECAR	4
12	SLEN-SERDP	1
6	SLEN-SERDP	2
13	SLEN-SERDP	3
8	SRWG-SERDP	1
3	SRWG-SERDP	2
10	SRWG-SERDP	3
20	SRWG-SERDP	4
4	SYNA	1
8	SYNA	2
20	SYNA	3
15	SYNA	4
6	TRAILHEAD	1
14	TRAILHEAD	2
6	TRAILHEAD	3
13	TRAILHEAD	4
2	VAV-SERDP	1
1	VAV-SERDP	2
16	VAV-SERDP	3
4	VAV-SERDP	4
1	VAVILOV	1
15	VAVILOV	2
5	VAVILOV	3
14	WWG-SERDP	1
19	WWG-SERDP	2
3	WWG-SERDP	3
8	WWG-SERDP	4
18	WY-SERDP	1
9	WY-SERDP	2
12	WY-SERDP	3
9	WY-SERDP	4

Plot	Entry	Rep
1	SAND-SERDP	4
15	SAND-CK	1
18	SAND-CK	2
4	SAND-CK	3
17	SAND-CK	4

Plot	Entry	Rep
17	WY-CK	1
13	WY-CK	2
18	WY-CK	3
12	WY-CK	4

D.3 Camp Guernsey seeding lists (monocultures and mixtures)

Guernsey River Site. The River site is near the North Platte River (N 42° 15.001' W 104° 44.090'). Monocultures and mixtures were planted on 31 March 2004, with a plot size of 1.5 x 6 m (5 x 20 ft) with six rows at 2.5 cm (10 in.) apart (Table 39). There were 1.5-m (5-ft) borders of CD-II crested wheatgrass between replications. Starting in the southwest corner, rows were numbered form west to east; replications were numbered from south to north. Monoculture seeds were planted at a rate of approximately one seed/cm (2.5 seeds per linear inch). See Table 5 and Table 6 in Section 5.3.2 for mixture species and seeding rates.

Table 39. Guernsey River site monoculture and mixture seeding list (31 March 2004).

Entry	Row	Rep
AI Intermediate WG	25	1
AI Intermediate WG	5	2
AI Intermediate WG	9	3
Bannock Thickspike WG	29	1
Bannock Thickspike WG	8	2
Bannock Thickspike WG	5	3
Bozoisky RWR	2	1
Bozoisky RWR	10	2
Bozoisky RWR	4	3
Bozoisky X Tetra RWR	1	1
Bozoisky X Tetra RWR	28	2
Bozoisky X Tetra RWR	12	3
Camper Little Bluestem	31	1
Camper Little Bluestem	34	2
Camper Little Bluestem	24	3
Flintlock Western WG	15	1
Flintlock Western WG	32	2

Entry	Row	Rep
P-7 Bluebunch WG	12	1
P-7 Bluebunch WG	15	2
P-7 Bluebunch WG	20	3
Pryor Slender WG	4	1
Pryor Slender WG	24	2
Pryor Slender WG	1	3
Roadcrest Crested WG	7	1
Roadcrest Crested WG	14	2
Roadcrest Crested WG	21	3
Rosana Western WG	17	1
Rosana Western WG	19	2
Rosana Western WG	18	3
SB-2 Western WG	16	1
SB-2 Western WG	22	2
SB-2 Western WG	7	3
Secar Snake River WG	13	1
Secar Snake River WG	18	2

Entry	Row	Rep
Flintlock Western WG	19	3
Goldar Bluebunch WG	11	1
Goldar Bluebunch WG	31	2
Goldar Bluebunch WG	23	3
Kazak Pub. Siberian WG	8	1
Kazak Pub. Siberian WG	20	2
Kazak Pub. Siberian WG	14	3
Lovington Blue Grama	27	1
Lovington Blue Grama	25	2
Lovington Blue Grama	30	3
Mix 1 - Introduced	23	1
Mix 1 - Introduced	6	2
Mix 1 - Introduced	11	3
Mix 2 - Native	24	1
Mix 2 - Native	17	2
Mix 2 - Native	25	3
Mix 3 - Guernsey	26	1
Mix 3 - Guernsey	27	2
Mix 3 - Guernsey	6	3
Mix 4 - core native	28	1
Mix 4 - core native	21	2
Mix 4 - core native	32	3
Mix 5 - core + AI IWG	30	1
Mix 5 - core + AI IWG	33	2
Mix 5 - core + AI IWG	22	3
Mix 6 - core + SERDP Sib.WG	32	1
Mix 6 - core + SERDP Sib.WG	2	2
Mix 6 - core + SERDP Sib.WG	29	3
Mix 7 - core + SERDP RWR	34	1
Mix 7 - core + SERDP RWR	26	2
Mix 7 - core + SERDP RWR	17	3

Entry	Row	Rep
Secar Snake River WG	26	3
SERDP Basin WR	20	1
SERDP Basin WR	23	2
SERDP Basin WR	3	3
SERDP Slender WG	5	1
SERDP Slender WG	12	2
SERDP Slender WG	34	3
SERDP Slender WG - Rhiz.	6	1
SERDP Slender WG - Rhiz.	3	2
SERDP Slender WG - Rhiz.	15	3
SERDP Snake River WG	14	1
SERDP Snake River WG	9	2
SERDP Snake River WG	2	3
SERDP Syn A RWR	3	1
SERDP Syn A RWR	11	2
SERDP Syn A RWR	33	3
SERDP TC-2 Western WG	18	1
SERDP TC-2 Western WG	7	2
SERDP TC-2 Western WG	13	3
SERDP Vavilov Siberian WG	10	1
SERDP Vavilov Siberian WG	13	2
SERDP Vavilov Siberian WG	16	3
SERDP Western Yarrow	22	1
SERDP Western Yarrow	4	2
SERDP Western Yarrow	28	3
Texoka Buffalo Grass	33	1
Texoka Buffalo Grass	30	2
Texoka Buffalo Grass	31	3
Trailhead Basin WR	19	1

Guernsey Tower Site. The site near the Guernsey Radar Tower (N 42° 14.385' W 104° 44.302'; elevation 1,305 m [4,580 ft]) was planted with monocultures and mixes 23 March 2005 (Table 40), with a plot size of 1.5 x 6 m (5 x 20 ft) with six rows at 2.5 cm (10 in.) apart. There were 1.5-m (5-ft) borders of CD-II crested wheatgrass between replications. Starting in the southwest corner rows were numbered from west to east and replications from south to north. Monoculture seeds were planted at a rate of approximately one seed/cm (2.5 seeds per linear inch). See Table 5 and Table 6 in Section 5.3.2 for mixture species and seeding rates.

Table 40. Guernsey Tower site monoculture and mixture seedings (23 March 2005).

Entry	Row	Rep
AI Intermediate WG	25	1
AI Intermediate WG	5	2
AI Intermediate WG	9	3
Bannock Thickspike WG	29	1
Bannock Thickspike WG	8	2
Bannock Thickspike WG	5	3
Bozoisky RWR	2	1
Bozoisky RWR	10	2
Bozoisky RWR	4	3
Bozoisky X Tetra RWR	1	1
Bozoisky X Tetra RWR	28	2
Bozoisky X Tetra RWR	12	3
Camper Little Bluestem	31	1
Camper Little Bluestem	34	2
Camper Little Bluestem	24	3
Flintlock Western WG	15	1
Flintlock Western WG	32	2
Flintlock Western WG	19	3
Goldar Bluebunch WG	11	1
Goldar Bluebunch WG	31	2
Goldar Bluebunch WG	23	3
Kazak Pub. Siberian WG	8	1
Kazak Pub. Siberian WG	20	2
Kazak Pub. Siberian WG	14	3
Lovington Blue Grama	27	1
Lovington Blue Grama	25	2

Entry	Row	Rep
Pryor Slender WG	4	1
Pryor Slender WG	24	2
Pryor Slender WG	1	3
Roadcrest Crested WG	7	1
Roadcrest Crested WG	14	2
Roadcrest Crested WG	21	3
Rosana Western WG	17	1
Rosana Western WG	19	2
Rosana Western WG	18	3
SB-2 Western WG	16	1
SB-2 Western WG	22	2
SB-2 Western WG	7	3
Secar Snake River WG	13	1
Secar Snake River WG	18	2
Secar Snake River WG	26	3
SERDP Basin WR	20	1
SERDP Basin WR	23	2
SERDP Basin WR	3	3
SERDP Slender WG	5	1
SERDP Slender WG	12	2
SERDP Slender WG	34	3
SERDP Slender WG - Rhiz.	6	1
SERDP Slender WG - Rhiz.	3	2
SERDP Slender WG - Rhiz.	15	3
SERDP Snake River WG	14	1
SERDP Snake River WG	9	2

Entry	Row	Rep
Lovington Blue Grama	30	3
Mix 1 - Introduced	23	1
Mix 1 - Introduced	6	2
Mix 1 - Introduced	11	3
Mix 2 - Native	24	1
Mix 2 - Native	17	2
Mix 2 - Native	25	3
Mix 3 - Guernsey	26	1
Mix 3 - Guernsey	27	2
Mix 3 - Guernsey	6	3
Mix 4 - core native	28	1
Mix 4 - core native	21	2
Mix 4 - core native	32	3
Mix 5 - core + AI IWG	30	1
Mix 5 - core + AI IWG	33	2
Mix 5 - core + AI IWG	22	3
Mix 6 - core + SERDP Sib.WG	32	1
Mix 6 - core + SERDP Sib.WG	2	2
Mix 6 - core + SERDP Sib.WG	29	3
Mix 7 - core + SERDP RWR	34	1
Mix 7 - core + SERDP RWR	26	2
Mix 7 - core + SERDP RWR	17	3
P-7 Bluebunch WG	12	1
P-7 Bluebunch WG	15	2
P-7 Bluebunch WG	20	3

Entry	Row	Rep
SERDP Snake River WG	2	3
SERDP Syn A RWR	3	1
SERDP Syn A RWR	11	2
SERDP Syn A RWR	33	3
SERDP TC-2 Western WG	18	1
SERDP TC-2 Western WG	7	2
SERDP TC-2 Western WG	13	3
SERDP Vavilov Siberian WG	10	1
SERDP Vavilov Siberian WG	13	2
SERDP Vavilov Siberian WG	16	3
SERDP Western Yarrow	22	1
SERDP Western Yarrow	4	2
SERDP Western Yarrow	28	3
Texoka Buffalo Grass	33	1
Texoka Buffalo Grass	30	2
Texoka Buffalo Grass	31	3
Trailhead Basin WR	19	1
Trailhead Basin WR	29	2
Trailhead Basin WR	27	3
Vavilov Siberian WG	9	1
Vavilov Siberian WG	16	2
Vavilov Siberian WG	8	3
Western Yarrow Check	21	1
Western Yarrow Check	1	2
Western Yarrow Check	10	3

D.4 Dugway Proving Ground seeding list (monocultures)

The Dugway site was seeded with monocultures 7 November 2005 (Table 41) with a plot size of 1.5 x 6 m (5 x 20 ft). There were two ranges per replication and two blocks of grasses. Starting in the southeast corner,

rows were numbered from south to north; ranges were numbered from east to west.

Table 41. Dugway monoculture seeding list (7 November 2005).

Rep	Row	Range	Entry	Entry #	Block
1	1	1	Greenar Intermediate WG	1	1
1	2	1	I 1871 Intermediate WG	2	1
1	3	1	Al Intermediate WG	3	1
1	4	1	Nordan – CWG	4	1
1	5	1	Hycrest – CWG	5	1
1	6	1	Hycrest II – Foundation Richmond	6	1
1	7	1	HxB28 – Nephi 2004 (bulk selected)	7	1
1	8	1	CD-II – Foundation Richmond	8	1
1	9	1	Cool Season Crested – Evans (2004)	9	1
1	10	1	NDAD 1 A.desertorum CWG	10	1
1	11	1	NDAD 2 A.desertorum CWG	11	1
1	12	1	NDAD 3 A.desertorum CWG	12	1
1	13	1	Manchar Smooth Brome	13	1
1	14	1	Smooth Bromegrass (Bluecreek 04)	14	1
1	15	1	San Luis – Slender WG	15	1
1	16	1	Army Slender WG 02	16	1
1	17	1	Pryor – Slender WG	17	1
1	18	1	Revenue Slender WG	18	1
1	19	1	Rhizome Slender – Nephi 2005	19	1
1	20	1	Swift – RWR	20	1
1	21	1	Bozoisky II	21	1
1	22	1	Bozoisky RWR	22	1
1	23	1	Diploid RWR – Nephi 2004	23	1
1	24	1	BozXTet RWR – Nephi 2004	24	1
1	25	1	Critana TWG	25	1
1	26	1	Bannock TWG	26	1
1	27	1	Exp. Blue Creek TWG	27	1
1	28	1	Sodar TWG	28	1
1	29	1	Schwendimar TWG	29	1
1	30	1	Salina Wildrye – Lakeside 97	30	1
1	31	1	Salina Wildrye – Nephi 2005	31	1
1	32	1	BC 118	63	2
1	33	1	Immigrant	64	2
1	34	1	KZ6X Select	65	2

Rep	Row	Range	Entry	Entry #	Block
1	35	1	Sahro	66	2
1	36	1	Karnabchulsky	67	2
1	1	2	Arriba WWG	32	1
1	2	2	Barton WWG	33	1
1	3	2	SB-3 WWG	34	1
1	4	2	TC-3 WWG	35	1
1	5	2	Rosana WWG	36	1
1	6	2	Rodan WWG	37	1
1	7	2	Expedition Snake River WG	38	1
1	8	2	Secar Snake River WG	39	1
1	9	2	Snake River BC 04	40	1
1	10	2	Snake River N – Nephi 2005	41	1
1	11	2	Pubescent Siberian WG	42	1
1	12	2	Vavilov – Foundation North Logan 04	43	1
1	13	2	Vavilov Select – Blue Creek 04	44	1
1	14	2	Vavilov Select –Nephi 2005	45	1
1	15	2	Anatone BBWG	46	1
1	16	2	Goldar BBWG	47	1
1	17	2	Columbia BBWG	48	1
1	18	2	P-19 BBWG	49	1
1	19	2	P-7 BBWG	50	1
1	20	2	Sand Hollow BBST	51	1
1	21	2	Fish Creek BBST	52	1
1	22	2	Toe Jam Creek BBST	53	1
1	23	2	Trailhead BWR	54	1
1	24	2	L-45 BWR	55	1
1	25	2	L-46 BWR	56	1
1	26	2	L-54 BWR (Lahontan)	57	1
1	27	2	Basin WR – Army H Field 2004	58	1
1	28	2	Magnar BWR	59	1
1	29	2	Nezpar IRG	60	1
1	30	2	White River IRG 2003	61	1
1	31	2	Rimrock IRG	62	1
1	32	2	Otavny	68	2
1	33	2	Pustinny	69	2
1	34	2	Yakima Yarrow	70	2
1	35	2	Yarrow Check	71	2

Rep	Row	Range	Entry	Entry #	Block
1	36	2	Filler	72	2
2	1	3	San Luis – Slender WG	15	1
2	2	3	Greenar Intermediate WG	1	1
2	3	3	Vavilov – Foundation North Logan 04	43	1
2	4	3	Swift – RWR	20	1
2	5	3	Vavilov Select – Blue Creek 04	44	1
2	6	3	Goldar BBWG	47	1
2	7	3	Nezpar IRG	60	1
2	8	3	CD-II – Foundation Richmond	8	1
2	9	3	Fish Creek BBST	52	1
2	10	3	Magnar BWR	59	1
2	11	3	Expedition Snake River WG	38	1
2	12	3	Smooth Bromegrass (Bluecreek 04)	14	1
2	13	3	Diploid RWR – Nephi 2004	23	1
2	14	3	Bozoisky II	21	1
2	15	3	P-19 BBWG	49	1
2	16	3	TC-3 WWG	35	1
2	17	3	Bozoisky RWR	22	1
2	18	3	Pubescent Siberian WG	42	1
2	19	3	Sodar TWG	28	1
2	20	3	Manchar Smooth Brome	13	1
2	21	3	P-7 BBWG	50	1
2	22	3	Army Slender WG 02	16	1
2	23	3	Snake River N – Nephi 2005	41	1
2	24	3	L-46 BWR	56	1
2	25	3	Snake River BC 04	40	1
2	26	3	Sand Hollow BBST	51	1
2	27	3	L-54 BWR (Lahontan)	57	1
2	28	3	Anatone BBWG	46	1
2	29	3	HxB28 – Nephi 2004 (bulk selected)	7	1
2	30	3	Columbia BBWG	48	1
2	31	3	BozXTet RWR – Nephi 2004	24	1
2	32	3	Yakima Yarrow	70	2
2	33	3	Otavny	68	2
2	34	3	KZ6X Select	65	2
2	35	3	Sahro	66	2
2	36	3	Yarrow Check	71	2

Rep	Row	Range	Entry	Entry #	Block
2	1	4	Pryor – Slender WG	17	1
2	2	4	Rodan WWG	37	1
2	3	4	Hycrest – CWG	5	1
2	4	4	Trailhead BWR	54	1
2	5	4	Cool Season Crested – Evans (2004)	9	1
2	6	4	Hycrest II – Foundation Richmond	6	1
2	7	4	Salina Wildrye – Lakeside 97	30	1
2	8	4	NDAD 1 A.desertorum CWG	10	1
2	9	4	Revenue Slender WG	18	1
2	10	4	AI Intermediate WG	3	1
2	11	4	NDAD 3 A.desertorum CWG	12	1
2	12	4	Barton WWG	33	1
2	13	4	White River IRG 2003	61	1
2	14	4	NDAD 2 A.desertorum CWG	11	1
2	15	4	I 1871 Intermediate WG	2	1
2	16	4	Bannock TWG	26	1
2	17	4	Salina Wildrye – Nephi 2005	31	1
2	18	4	SB-3 WWG	34	1
2	19	4	L-45 BWR	55	1
2	20	4	Basin WR – Army H Field 2004	58	1
2	21	4	Toe Jam Creek BBST	53	1
2	22	4	Rosana WWG	36	1
2	23	4	Arriba WWG	32	1
2	24	4	Critana TWG	25	1
2	25	4	Nordan – CWG	4	1
2	26	4	Schwendimar TWG	29	1
2	27	4	Secar Snake River WG	39	1
2	28	4	Rhizome Slender – Nephi 2005	19	1
2	29	4	Rimrock IRG	62	1
2	30	4	Exp. Blue Creek TWG	27	1
2	31	4	Vavilov Select –Nephi 2005	45	1
2	32	4	Karnabchulsky	67	2
2	33	4	Filler	72	2
2	34	4	Immigrant	64	2
2	35	4	BC 118	63	2
2	36	4	Pustinny	69	2
3	1	5	Salina Wildrye – Lakeside 97	30	1

Rep	Row	Range	Entry	Entry #	Block
3	2	5	Arriba WWG	32	1
3	3	5	Expedition Snake River WG	38	1
3	4	5	San Luis – Slender WG	15	1
3	5	5	Pryor – Slender WG	17	1
3	6	5	Snake River BC 04	40	1
3	7	5	HxB28 – Nephi 2004 (bulk selected)	7	1
3	8	5	Sodar TWG	28	1
3	9	5	NDAD 1 A.desertorum CWG	10	1
3	10	5	Swift – RWR	20	1
3	11	5	Hycrest II – Foundation Richmond	6	1
3	12	5	SB-3 WWG	34	1
3	13	5	White River IRG 2003	61	1
3	14	5	Army Slender WG 02	16	1
3	15	5	Bozoisky RWR	22	1
3	16	5	Revenue Slender WG	18	1
3	17	5	Salina Wildrye – Nephi 2005	31	1
3	18	5	Cool Season Crested – Evans (2004)	9	1
3	19	5	Trailhead BWR	54	1
3	20	5	Manchar Smooth Brome	13	1
3	21	5	AI Intermediate WG	3	1
3	22	5	Anatone BBWG	46	1
3	23	5	BozXTet RWR – Nephi 2004	24	1
3	24	5	P-19 BBWG	49	1
3	25	5	Bozoisky II	21	1
3	26	5	NDAD 2 A.desertorum CWG	11	1
3	27	5	Basin WR – Army H Field 2004	58	1
3	28	5	Exp. Blue Creek TWG	27	1
3	29	5	P-7 BBWG	50	1
3	30	5	Bannock TWG	26	1
3	31	5	Nezpar IRG	60	1
3	32	5	Karnabchulsky	67	2
3	33	5	Sahro	66	2
3	34	5	Otavny	68	2
3	35	5	BC 118	63	2
3	36	5	Filler	72	2
3	1	6	Vavilov Select – Blue Creek 04	44	1
3	2	6	Nordan – CWG	4	1

Rep	Row	Range	Entry	Entry #	Block
3	3	6	Greenar Intermediate WG	1	1
3	4	6	Fish Creek BBST	52	1
3	5	6	Toe Jam Creek BBST	53	1
3	6	6	L-54 BWR (Lahontan)	57	1
3	7	6	Rodan WWG	37	1
3	8	6	Hycrest – CWG	5	1
3	9	6	CD-II – Foundation Richmond	8	1
3	10	6	Magnar BWR	59	1
3	11	6	L-45 BWR	55	1
3	12	6	Barton WWG	33	1
3	13	6	Rimrock IRG	62	1
3	14	6	Snake River N – Nephi 2005	41	1
3	15	6	Critana TWG	25	1
3	16	6	Vavilov Select –Nephi 2005	45	1
3	17	6	Sand Hollow BBST	51	1
3	18	6	Pubescent Siberian WG	42	1
3	19	6	Secar Snake River WG	39	1
3	20	6	TC-3 WWG	35	1
3	21	6	L-46 BWR	56	1
3	22	6	Columbia BBWG	48	1
3	23	6	Rosana WWG	36	1
3	24	6	Smooth Bromegrass (Bluecreek 04)	14	1
3	25	6	I 1871 Intermediate WG	2	1
3	26	6	Schwendimar TWG	29	1
3	27	6	NDAD 3 A.desertorum CWG	12	1
3	28	6	Vavilov – Foundation North Logan 04	43	1
3	29	6	Diploid RWR – Nephi 2004	23	1
3	30	6	Goldar BBWG	47	1
3	31	6	Rhizome Slender – Nephi 2005	19	1
3	32	6	Pustinny	69	2
3	33	6	Yakima Yarrow	70	2
3	34	6	Immigrant	64	2
3	35	6	Yarrow Check	71	2
3	36	6	KZ6X Select	65	2
4	1	7	SB-3 WWG	34	1
4	2	7	Smooth Bromegrass (Bluecreek 04)	14	1
4	3	7	San Luis – Slender WG	15	1

Rep	Row	Range	Entry	Entry #	Block
4	4	7	I 1871 Intermediate WG	2	1
4	5	7	TC-3 WWG	35	1
4	6	7	Barton WWG	33	1
4	7	7	Anatone BBWG	46	1
4	8	7	Revenue Slender WG	18	1
4	9	7	Magnar BWR	59	1
4	10	7	NDAD 2 A.desertorum CWG	11	1
4	11	7	Snake River BC 04	40	1
4	12	7	Bannock TWG	26	1
4	13	7	Goldar BBWG	47	1
4	14	7	Critana TWG	25	1
4	15	7	Vavilov Select – Blue Creek 04	44	1
4	16	7	Nordan – CWG	4	1
4	17	7	NDAD 1 A.desertorum CWG	10	1
4	18	7	Schwendimar TWG	29	1
4	19	7	P-7 BBWG	50	1
4	20	7	Basin WR – Army H Field 2004	58	1
4	21	7	Exp. Blue Creek TWG	27	1
4	22	7	Salina Wildrye – Lakeside 97	30	1
4	23	7	Greenar Intermediate WG	1	1
4	24	7	Rhizome Slender – Nephi 2005	19	1
4	25	7	Salina Wildrye – Nephi 2005	31	1
4	26	7	Sodar TWG	28	1
4	27	7	L-54 BWR (Lahontan)	57	1
4	28	7	Sand Hollow BBST	51	1
4	29	7	Hycrest II – Foundation Richmond	6	1
4	30	7	P-19 BBWG	49	1
4	31	7	Pryor – Slender WG	17	1
4	32	7	KZ6X Select	65	2
4	33	7	Yarrow Check	71	2
4	34	7	Karnabchulsky	67	2
4	35	7	Pustinny	69	2
4	36	7	Otavny	68	2
4	1	8	White River IRG 2003	61	1
4	2	8	Bozoisky RWR	22	1
4	3	8	Pubescent Siberian WG	42	1
4	4	8	HxB28 – Nephi 2004 (bulk selected)	7	1

Rep	Row	Range	Entry	Entry #	Block
4	5	8	Swift – RWR	20	1
4	6	8	Cool Season Crested – Evans (2004)	9	1
4	7	8	NDAD 3 A.desertorum CWG	12	1
4	8	8	Manchar Smooth Brome	13	1
4	9	8	Diploid RWR – Nephi 2004	23	1
4	10	8	Hycrest – CWG	5	1
4	11	8	Fish Creek BBST	52	1
4	12	8	Rimrock IRG	62	1
4	13	8	Trailhead BWR	54	1
4	14	8	Expedition Snake River WG	38	1
4	15	8	BozXTet RWR – Nephi 2004	24	1
4	16	8	Vavilov Select –Nephi 2005	45	1
4	17	8	L-46 BWR	56	1
4	18	8	Arriba WWG	32	1
4	19	8	Army Slender WG 02	16	1
4	20	8	Columbia BBWG	48	1
4	21	8	CD-II – Foundation Richmond	8	1
4	22	8	Toe Jam Creek BBST	53	1
4	23	8	Nezpar IRG	60	1
4	24	8	L-45 BWR	55	1
4	25	8	Rosana WWG	36	1
4	26	8	Vavilov – Foundation North Logan 04	43	1
4	27	8	Snake River N – Nephi 2005	41	1
4	28	8	Rodan WWG	37	1
4	29	8	Bozoisky II	21	1
4	30	8	Secar Snake River WG	39	1
4	31	8	Al Intermediate WG	3	1
4	32	8	Sahro	66	2
4	33	8	Immigrant	64	2
4	34	8	BC 118	63	2
4	35	8	Filler	72	2
4	36	8	Yakima Yarrow	70	2

D.5 Yakima Training Center data (monocultures and mixtures)

The following raw data from YTC Exit 11 gives values for monocultures and mixes (Table 42). For the 6-month establishment measurements taken on

14 May 2003, we counted the number of gaps as the number of 6.35 x 6.35 cm (2.5 x 2.5 in.) squares without plants over a total of 48 squares over four subsamples for each entry.

Table 42. Yakima Training Center monocultures and mixes 6-month establishment on 14 May 2003 (48-grid frame with 6.35 x 6.35-cm squares).

Entries	Rep	Subsamples of no. of empty squares in a 48-grid frame				% establishment	Mean % establishment
		1	2	3	4		
Bluebunch WG-SERDP Select	1	35	37	38	33	26	
Bluebunch WG-SERDP Select	2	38	3	25	31	49	
Bluebunch WG-SERDP Select	3	27	36	28	29	38	
Bluebunch WG-SERDP Select	4	48	48	46	36	7	30
BozXTet RWR	1	28	21	16	16	58	
BozXTet RWR	2	33	38	33	11	40	
BozXTet RWR	3	15	16	30	34	51	
BozXTet RWR	4	35	26	26	32	38	46.75
Goldar BWG	1	26	22	25	39	42	
Goldar BWG	2	45	42	42	23	21	
Goldar BWG	3	42	37	35	11	35	
Goldar BWG	4	32	40	25	35	31	32.25
Mix-1-Introduced	1	41	44	40	43	13	
Mix-1-Introduced	2	11	24	34	1	64	
Mix-1-Introduced	3	14	23	26	21	56	
Mix-1-Introduced	4	39	26	29	17	42	43.75
Mix-2-Native	1	30	37	33	32	31	
Mix-2-Native	2	24	21	25	18	54	
Mix-2-Native	3	19	27	39	13	49	
Mix-2-Native	4	39	17	28	32	40	43.5
Pryor Slender WG	1	35	26	29	23	41	
Pryor Slender WG	2	25	9	13	34	58	
Pryor Slender WG	3	23	34	22	26	45	
Pryor Slender WG	4	13	40	16	21	53	49.25
Roadcrest CWG	1	47	38	45	34	15	

Entries	Rep	Subsamples of no. of empty squares in a 48-grid frame				% establishment	Mean % establishment
		1	2	3	4		
Roadcrest CWG	2	7	45	29	16	49	
Roadcrest CWG	3	29	46	22	34	32	
Roadcrest CWG	4	20	29	38	25	42	34.5
Rosana WWG	1	39	34	23	33	33	
Rosana WWG	2	35	7	25	18	56	
Rosana WWG	3	23	28	39	15	45	
Rosana WWG	4	34	44	33	35	24	39.5
Sandberg BG-Check	1	48	47	48	48	1	
Sandberg BG-Check	2	38	23	47	37	24	
Sandberg BG-Check	3	48	47	48	44	3	
Sandberg BG-Check	4	48	48	38	48	5	8.25
Sandberg BG-SERDP Select	1	48	48	48	47	1	
Sandberg BG-SERDP Select	2	48	48	48	47	1	
Sandberg BG-SERDP Select	3	47	35	45	48	9	
Sandberg BG-SERDP Select	4	46	48	41	42	8	4.75
Secar Snake River WG	1	43	35	32	39	22	
Secar Snake River WG	2	25	28	36	26	40	
Secar Snake River WG	3	27	21	8	15	63	
Secar Snake River WG	4	35	16	43	32	34	39.75
Slender WG-SERDP Select	1	6	14	22	31	62	
Slender WG-SERDP Select	2	1	5	15	5	86	
Slender WG-SERDP Select	3	9	6	5	4	88	
Slender WG-SERDP Select	4	1	6	7	4	91	81.75
Snake River-SERDP Select	1	28	42	26	38	30	
Snake River-SERDP Select	2	21	33	36	34	35	
Snake River-SERDP Select	3	40	44	38	24	24	

Entries	Rep	Subsamples of no. of empty squares in a 48-grid frame				% establishment	Mean % establishment
		1	2	3	4		
Snake River-SERDP Select	4	38	41	38	32	22	27.75
Syn-A RWR	1	8	21	15	28	63	
Syn-A RWR	2	12	9	17	14	73	
Syn-A RWR	3	32	37	41	27	29	
Syn-A RWR	4	18	29	32	17	50	53.75
Trailhead Basin WR	1	42	45	31	37	19	
Trailhead Basin WR	2	46	39	47	35	13	
Trailhead Basin WR	3	27	39	31	27	35	
Trailhead Basin WR	4	40	36	38	37	21	22
Vavilov Siberian WG	1	42	45	29	44	17	
Vavilov Siberian WG	2	45	35	32	26	28	
Vavilov Siberian WG	3	41	40	46	39	14	
Vavilov Siberian WG	4	19	31	36	43	33	23
Vavilov-SERDP Select Siberian WG	1	21	31	17	45	41	
Vavilov-SERDP Select Siberian WG	2	3	34	15	16	65	
Vavilov-SERDP Select Siberian WG	3	23	22	34	44	36	
Vavilov-SERDP Select Siberian WG	4	4	20	13	26	67	52.25
Western WG-SERDP Select	1	15	18	12	27	63	
Western WG-SERDP Select	2	14	6	4	17	79	
Western WG-SERDP Select	3	13	15	14	12	72	
Western WG-SERDP Select	4	10	14	6	12	78	73
Western Yarrow-Check	1	42	48	47	43	6	
Western Yarrow-Check	2	47	48	48	47	1	
Western Yarrow-Check	3	48	47	48	46	2	
Western Yarrow-Check	4	41	41	47	47	8	4.25
Western Yarrow-SERDP Select	1	46	48	47	44	4	

Entries	Rep	Subsamples of no. of empty squares in a 48-grid frame				% establishment	Mean % establishment
		1	2	3	4		
Western Yarrow-SERDP Select	2	47	48	48	48	1	
Western Yarrow-SERDP Select	3	43	44	47	48	5	
Western Yarrow-SERDP Select	4	48	45	42	47	5	3.75

YTC data were taken 19 April 2004 and June 2005. This time, larger squares were measured: we counted the number of 12.7 x 12.7-cm (5 x 5-in.) squares out of 24 over three subsamples (Table 43 and Table 44).

Table 43. Yakima Training Center monocultures and mixes at 1.5 years on 19 April 2004 (24-grid frame with 12.7 x 12.7-cm squares).

Plot	Entry	Rep	Subsamples of no. of empty squares in a 24-grid frame			Percent stand	Mean gaps	Mean percent stand
			1	2	3			
10	BBWG-SERDP	1	19	17	20	22		
16	BBWG-SERDP	2	13	4	10	63		
9	BBWG-SERDP	3	3	10	4	76		
11	BBWG-SERDP	4	21	18	15	25	13	47
5	BOZXTET	1	10	5	1	78		
12	BOZXTET	2	11	20	16	35		
15	BOZXTET	3	2	6	10	75		
3	BOZXTET	4	10	15	11	50	10	60
9	GOLDAR	1	17	11	18	36		
10	GOLDAR	2	11	16	16	40		
8	GOLDAR	3	5	11	16	56		
14	GOLDAR	4	20	16	18	25	15	39
19	MIX-1	1	18	21	22	15		
4	MIX-1	2	1	5	1	90		
17	MIX-1	3	7	8	7	69	10	58
20	MIX-2	1	17	20	10	35		
2	MIX-2	2	8	5	5	75		
7	MIX-2	3	13	8	4	65		

Plot	Entry	Rep	Subsamples of no. of empty squares in a 24-grid frame			Percent stand	Mean gaps	Mean percent stand
			1	2	3			
10	MIX-2	4	9	6	15	58	10	58
11	PRYOR	1	19	13	13	38		
20	PRYOR	2	5	6	12	68		
19	PRYOR	3	24	17	15	22		
16	PRYOR	4	6	10	11	63	13	48
3	ROADCREST	1	21	13	16	31		
5	ROADCREST	2	2	11	2	79		
2	ROADCREST	3	11	2	6	74		
2	ROADCREST	4	20	15	8	40	11	56
13	ROSANA	1	14	13	13	44		
17	ROSANA	2	3	7	3	82		
11	ROSANA	3	8	11	2	71		
19	ROSANA	4	20	19	22	15	11	53
16	SAND-SERDP	1	24	24	24	0		
11	SAND-SERDP	2	24	24	24	0		
14	SAND-SERDP	3	24	24	24	0		
1	SAND-SERDP	4	20	24	20	11	23	3
15	SAND-CK	1	24	24	24	0		
18	SAND-CK	2	11	17	16	39		
4	SAND-CK	3	23	24	23	3		
17	SAND-CK	4	24	21	24	4	21	12
7	SECAR	1	14	16	12	42		
7	SECAR	2	4	6	7	76		
1	SECAR	3	2	4	8	81		
18	SECAR	4	21	16	12	32	10	58
12	SLEN-SERDP	1	4	15	24	40		
6	SLEN-SERDP	2	3	4	4	85		
13	SLEN-SERDP	3	7	4	2	82	7	69
8	SRWG-SERDP	1	20	15	19	25		
3	SRWG-SERDP	2	9	18	11	47		
10	SRWG-SERDP	3	11	3	17	57		
20	SRWG-SERDP	4	16	18	13	35	14	41
4	SYNA	1	3	1	9	82		
8	SYNA	2	4	4	3	85		
20	SYNA	3	20	23	17	17		

Plot	Entry	Rep	Subsamples of no. of empty squares in a 24-grid frame			Percent stand	Mean gaps	Mean percent stand
			1	2	3			
15	SYNA	4	7	3	2	83	8	67
6	TRAILHEAD	1	21	18	20	18		
14	TRAILHEAD	2	23	21	21	10		
6	TRAILHEAD	3	6	15	8	60		
13	TRAILHEAD	4	14	14	12	44	16	33
2	VAV-SERDP	1	13	18	13	39		
1	VAV-SERDP	2	4	2	2	89		
16	VAV-SERDP	3	9	18	12	46		
4	VAV-SERDP	4	6	3	7	78	9	63
1	VAVILOV	1	20	17	22	18		
15	VAVILOV	2	17	9	19	38		
5	VAVILOV	3	16	16	17	32	17	29
14	WWG-SERDP	1	11	4	8	68		
19	WWG-SERDP	2	1	1	3	93		
3	WWG-SERDP	3	4	3	7	81		
8	WWG-SERDP	4	6	5	3	81	5	81
18	WY-SERDP	1	24	23	15	14		
9	WY-SERDP	2	24	22	22	6		
12	WY-SERDP	3	22	19	22	13		
9	WY-SERDP	4	23	20	22	10	22	11
17	WY-CK	1	21	22	24	7		
13	WY-CK	2	23	24	22	4		
18	WY-CK	3	23	24	21	6		
12	WY-CK	4	20	22	24	8	23	6

Table 44. Yakima Training Center monocultures and mixes at 2.5 years in June 2005 (24-grid frame with 12.7 x 12.7-cm squares).

Plot	Entry	Row	Subsamples of no. of empty squares in a 24-grid frame					Percent stand	Mean percent stand
			1	2	3	4	5		
10	Bluebunch WG-SERDP Select	1	12	20	16	12	4	47	
16	Bluebunch WG-SERDP Select	2	21	11	4	13	12	49	
9	Bluebunch WG-SERDP Select	3	3	3	5	1	8	83	
11	Bluebunch WG-SERDP Select	4	21	24	23	18	19	13	48
5	BozXTet RWR	1	2	6	7	7	0	82	
12	BozXTet RWR	2	8	20	15	12	4	51	
15	BozXTet RWR	3	5	11	9	0	0	79	
3	BozXTet RWR	4	6	11	18	15	12	48	65
9	Goldar BWG	1	9	22	18	9	14	40	
10	Goldar BWG	2	17	19	23	11	8	35	
8	Goldar BWG	3	7	2	12	17	19	53	
14	Goldar BWG	4	21	12	13	22	13	33	40
19	Mix-1-Introduced	1	7	24	20	18	7	37	
4	Mix-1-Introduced	2	4	5	10	4	3	78	
17	Mix-1-Introduced	3	3	5	12	6	6	73	
5	Mix-1-Introduced	4	18	15	14	9	5	49	59
20	Mix-2-Native	1	20	14	16	8	11	43	
2	Mix-2-Native	2	9	12	5	10	6	65	
7	Mix-2-Native	3	2	6	7	18	4	69	
10	Mix-2-Native	4	8	15	9	11	12	54	58
11	Pryor Slender WG	1	19	17	18	13	19	28	
20	Pryor Slender WG	2	22	8	22	24	19	21	
19	Pryor Slender WG	3	20	24	21	21	1	28	
16	Pryor Slender WG	4	8	12	20	23	19	32	27
3	Roadcrest CWG	1	22	19	14	17	11	31	
5	Roadcrest CWG	2	0	3	17	5	0	79	
2	Roadcrest CWG	3	7	9	2	11	10	68	
2	Roadcrest CWG	4	7	10	20	12	3	57	59

Plot	Entry	Row	Subsamples of no. of empty squares in a 24-grid frame					Percent stand	Mean percent stand
			1	2	3	4	5		
13	Rosana WWG	1	10	4	6	15	8	64	
17	Rosana WWG	2	15	2	7	8	9	66	
11	Rosana WWG	3	1	0	9	8	11	76	
19	Rosana WWG	4	12	20	16	14	17	34	60
15	Sandberg BG-Check	1	24	24	24	24	24	0	
18	Sandberg BG-Check	2	24	12	19	21	18	22	
4	Sandberg BG-Check	3	21	24	22	24	24	4	
17	Sandberg BG-Check	4	22	21	21	24	24	7	8
16	Sandberg BG-SERDP Select	1	21	24	24	23	24	3	
11	Sandberg BG-SERDP Select	2	22	23	24	24	24	3	
14	Sandberg BG-SERDP Select	3	22	23	24	19	24	7	
1	Sandberg BG-SERDP Select	4	17	23	24	13	22	18	8
7	Secar Snake River WG	1	17	15	19	12	14	36	
7	Secar Snake River WG	2	12	2	13	7	3	69	
1	Secar Snake River WG	3	10	2	5	3	7	78	
18	Secar Snake River WG	4	14	10	15	22	15	37	55
12	Slender WG-SERDP Select	1	24	23	22	14	24	11	
6	Slender WG-SERDP Select	2	24	12	17	17	12	32	
13	Slender WG-SERDP Select	3	19	23	24	22	12	17	
7	Slender WG-SERDP Select	4	11	16	21	24	22	22	20
8	Snake River-SERDP Select	1	13	16	10	12	5	53	
3	Snake River-SERDP Select	2	5	9	20	15	10	51	
10	Snake River-SERDP Select	3	0	2	3	21	6	73	
20	Snake River-SERDP Select	4	14	16	16	18	9	39	54
4	Syn-A RWR	1	6	2	5	2	2	86	
8	Syn-A RWR	2	4	0	6	3	1	88	
20	Syn-A RWR	3	13	15	17	17	1	48	
15	Syn-A RWR	4	6	6	6	10	7	71	73
6	Trailhead Basin WR	1	8	13	21	21	22	29	

Plot	Entry	Row	Subsamples of no. of empty squares in a 24-grid frame					Percent stand	Mean percent stand
			1	2	3	4	5		
14	Trailhead Basin WR	2	24	24	21	23	16	10	
6	Trailhead Basin WR	3	6	17	9	16	12	50	
13	Trailhead Basin WR	4	13	18	14	18	13	37	31
1	Vavilov Siberian WG	1	16	16	8	13	9	48	
15	Vavilov Siberian WG	2	17	16	8	9	5	54	
5	Vavilov Siberian WG	3	10	8	10	20	20	43	
6	Vavilov Siberian WG	4	12	12	7	8	6	63	52
2	Vavilov-SERDP Select Siberian WG	1	16	3	12	6	6	64	
1	Vavilov-SERDP Select Siberian WG	2	3	13	4	4	2	78	
16	Vavilov-SERDP Select Siberian WG	3	8	3	4	9	9	73	
4	Vavilov-SERDP Select Siberian WG	4	8	7	2	5	9	74	72
14	Western WG-SERDP Select	1	5	7	3	11	3	76	
19	Western WG-SERDP Select	2	5	2	4	7	4	82	
3	Western WG-SERDP Select	3	0	3	7	1	3	88	
8	Western WG-SERDP Select	4	4	3	7	7	8	76	80
17	Western Yarrow-Check	1	21	24	16	23	19	14	
13	Western Yarrow-Check	2	21	24	23	24	22	5	
18	Western Yarrow-Check	3	24	23	24	22	22	4	
12	Western Yarrow-Check	4	24	23	22	22	21	7	8
18	Western Yarrow-SERDP Select	1	24	23	23	23	15	10	
9	Western Yarrow-SERDP Select	2	23	22	24	24	21	5	
12	Western Yarrow-SERDP Select	3	18	19	17	17	18	26	
9	Western Yarrow-SERDP Select	4	24	22	14	23	22	13	13

D.6 Camp Guernsey data (monocultures and mixtures)

The **Guernsey River site** was planted 31 March 2004 (Table 45). Establishment data were taken 2 months later on 2 June 2004 (Table 46); percent coverage data were taken in June over the next 2 years (Table 47).

Table 45. Guernsey River site establishment of monocultures and mixtures; data taken June 2, 2004 using three sub-samples in each replication (48-grid frame with 6.35 x 6.35-cm squares).

Entry	Row	Rep	No. of squares missing plants (out of 48)	No. of squares missing plants (out of 48)	No. of squares missing plants (out of 48)	Mean	Mean of reps
AI Intermediate WG	25	1	12	16	25	18	
AI Intermediate WG	5	2	21	27	33	27	
AI Intermediate WG	9	3	23	31	34	29	25
Bannock Thickspike WG	29	1	18	26	27	24	
Bannock Thickspike WG	8	2	9	17	15	14	
Bannock Thickspike WG	5	3	28	34	43	35	24
Bozoisky RWR	2	1	26	48	46	40	
Bozoisky RWR	10	2	34	42	42	39	
Bozoisky RWR	4	3	36	37	46	40	40
Bozoisky X Tetra RWR	1	1	22	22	15	20	
Bozoisky X Tetra RWR	28	2	7	20	23	17	
Bozoisky X Tetra RWR	12	3	20	17	29	22	19
Camper Little Bluestem	31	1	45	47	44	45	
Camper Little Bluestem	34	2	45	47	44	45	
Camper Little Bluestem	24	3	48	48	47	48	46
Flintlock Western WG	15	1	24	21	16	20	
Flintlock Western WG	32	2	22	19	13	18	
Flintlock Western WG	19	3	18	27	27	24	21
Goldar Bluebunch WG	11	1	17	35	40	31	
Goldar Bluebunch WG	31	2	35	30	30	32	
Goldar Bluebunch WG	23	3	9	14	17	13	25
Kazak Pub. Siberian WG	8	1	31	23	29	28	
Kazak Pub. Siberian WG	20	2	23	20	30	24	
Kazak Pub. Siberian WG	14	3	21	19	35	25	26
Lovington Blue Grama	27	1	47	47	43	46	
Lovington Blue Grama	25	2	48	48	48	48	
Lovington Blue Grama	30	3	48	47	47	47	47

Entry	Row	Rep	No. of squares missing plants (out of 48)	No. of squares missing plants (out of 48)	No. of squares missing plants (out of 48)	Mean	Mean of reps
Mix 1 - Introduced	23	1	9	28	27	21	
Mix 1 - Introduced	6	2	29	36	19	28	
Mix 1 - Introduced	11	3	36	36	32	35	28
Mix 2 - Native	24	1	14	20	16	17	
Mix 2 - Native	17	2	22	28	32	27	
Mix 2 - Native	25	3	20	29	31	27	24
Mix 3 - Guernsey	26	1	41	39	35	38	
Mix 3 - Guernsey	27	2	38	41	40	40	
Mix 3 - Guernsey	6	3	39	46	44	43	40
Mix 4 - core native	28	1	33	25	21	26	
Mix 4 - core native	21	2	28	25	21	25	
Mix 4 - core native	32	3	19	16	6	14	22
Mix 5 - core + AI IWG	30	1	20	33	29	27	
Mix 5 - core + AI IWG	33	2	11	17	27	18	
Mix 5 - core + AI IWG	22	3	23	29	10	21	22
Mix 6 - core + SERDP Sib.WG	32	1	15	25	19	20	
Mix 6 - core + SERDP Sib.WG	2	2	21	29	24	25	
Mix 6 - core + SERDP Sib.WG	29	3	10	18	19	16	20
Mix 7 - core + SERDP RWR	34	1	14	22	17	18	
Mix 7 - core + SERDP RWR	26	2	22	29	18	23	
Mix 7 - core + SERDP RWR	17	3	6	23	35	21	21
P-7 Bluebunch WG	12	1	37	36	30	34	
P-7 Bluebunch WG	15	2	31	21	24	25	
P-7 Bluebunch WG	20	3	22	19	25	22	27
Pryor Slender WG	4	1	30	32	24	29	
Pryor Slender WG	24	2	22	27	29	26	
Pryor Slender WG	1	3	37	43	36	39	31
Roadcrest Crested WG	7	1	47	47	48	47	
Roadcrest Crested WG	14	2	48	47	46	47	

Entry	Row	Rep	No. of squares missing plants (out of 48)	No. of squares missing plants (out of 48)	No. of squares missing plants (out of 48)	Mean	Mean of reps
Roadcrest Crested WG	21	3	45	40	42	42	46
Rosana Western WG	17	1	11	16	27	18	
Rosana Western WG	19	2	35	26	24	28	
Rosana Western WG	18	3	13	28	15	19	22
SB-2 Western WG	16	1	24	28	28	27	
SB-2 Western WG	22	2	11	11	14	12	
SB-2 Western WG	7	3	25	25	32	27	22
Secar Snake River WG	13	1	47	48	43	46	
Secar Snake River WG	18	2	48	48	47	48	
Secar Snake River WG	26	3	31	47	48	42	45
SERDP Basin WR	20	1	36	41	39	39	
SERDP Basin WR	23	2	48	31	48	42	
SERDP Basin WR	3	3	48	47	47	47	43
SERDP Slender WG	5	1	14	17	5	12	
SERDP Slender WG	12	2	7	12	8	9	
SERDP Slender WG	34	3	4	10	6	7	9
SERDP Slender WG - Rhiz.	6	1	23	18	32	24	
SERDP Slender WG - Rhiz.	3	2	36	34	44	38	
SERDP Slender WG - Rhiz.	15	3	35	24	25	28	30
SERDP Snake River WG	14	1	48	48	42	46	
SERDP Snake River WG	9	2	39	46	45	43	
SERDP Snake River WG	2	3	47	48	47	47	46
SERDP Syn A RWR	3	1	31	41	32	35	
SERDP Syn A RWR	11	2	28	25	23	25	
SERDP Syn A RWR	33	3	13	18	12	14	25
SERDP TC-2 Western WG	18	1	15	10	14	13	
SERDP TC-2 Western WG	7	2	19	19	20	19	
SERDP TC-2 Western WG	13	3	27	35	10	24	19
SERDP Vavilov Siberian WG	10	1	15	15	19	16	
SERDP Vavilov Siberian WG	13	2	34	25	24	28	
SERDP Vavilov Siberian WG	16	3	7	32	27	22	22
SERDP Western Yarrow	22	1	48	48	48	48	

Entry	Row	Rep	No. of squares missing plants (out of 48)	No. of squares missing plants (out of 48)	No. of squares missing plants (out of 48)	Mean	Mean of reps
SERDP Western Yarrow	4	2	48	48	48	48	
SERDP Western Yarrow	28	3	48	48	48	48	48
Texoka Buffalo Grass	33	1	27	19	20	22	
Texoka Buffalo Grass	30	2	16	31	32	26	
Texoka Buffalo Grass	31	3	31	30	35	32	27
Trailhead Basin WR	19	1	37	43	41	40	
Trailhead Basin WR	29	2	45	44	41	43	
Trailhead Basin WR	27	3	31	46	46	41	42
Vavilov Siberian WG	9	1	32	28	32	31	
Vavilov Siberian WG	16	2	23	22	25	23	
Vavilov Siberian WG	8	3	35	36	36	36	30
Western Yarrow Check	21	1	48	48	48	48	
Western Yarrow Check	1	2	48	48	48	48	
Western Yarrow Check	10	3	48	48	48	48	48

Table 46. Guernsey River site, 1-year percent stand and weed data taken 2 June 2005 (24-grid frame; 12.7-x 12.7-cm squares).

Entry	Row	Rep	Number of 24 squares without plants	Number of 24 squares without plants	Number of 24 squares without plants	Percent stand	% Weeds in plots (visual est.)
Bozoisky X Tetra RWR	1	1	9	15	14	47	70
Bozoisky RWR	2	1	14	24	21	18	85
SERDP Syn A RWR	3	1	16	20	22	19	70
Pryor Slender WG	4	1	20	17	16	26	75
SERDP Slender WG	5	1	9	12	12	54	20
SERDP Slender WG - Rhiz.	6	1	23	23	23	4	65
Roadcrest Crested WG	7	1	22	24	24	3	75
Kazak Pub. Siberian WG	8	1	6	13	9	61	30
Vavilov Siberian WG	9	1	13	10	12	51	5
SERDP Vavilov Siberian WG	10	1	7	8	13	61	0
Goldar Bluebunch WG	11	1	22	20	24	8	40
P-7 Bluebunch WG	12	1	16	13	20	32	60

Entry	Row	Rep	Number of 24 squares without plants	Number of 24 squares without plants	Number of 24 squares without plants	Percent stand	% Weeds in plots (visual est.)
Secar Snake River WG	13	1	24	23	23	3	70
SERDP Snake River WG	14	1	14	24	20	19	70
Flintlock Western WG	15	1	23	21	13	21	70
SB-2 Western WG	16	1	10	15	23	33	50
Rosana Western WG	17	1	5	10	6	71	30
SERDP TC-2 Western WG	18	1	7	1	4	83	20
Trailhead Basin WR	19	1	19	22	20	15	70
SERDP Basin WR	20	1	14	21	21	22	70
Western Yarrow Check	21	1	24	24	24	0	80
SERDP Western Yarrow	22	1	24	24	24	0	80
Mix 1 - Introduced	23	1	4	7	11	69	10
Mix 2 - Native	24	1	2	7	5	81	20
AI Intermediate WG	25	1	0	4	5	88	10
Mix 3 - Guernsey	26	1	15	17	13	38	35
Lovington Blue Grama	27	1	24	24	24	0	80
Mix 4 - core native	28	1	15	12	4	57	35
Bannock Thickspike WG	29	1	6	10	15	57	40
Mix 5 - core + AI IWG	30	1	16	12	9	49	45
Camper Little Bluestem	31	1	24	24	24	0	75
Mix 6 - core + SERDP Sib.WG	32	1	4	16	13	54	30
Texoka Buffalo Grass	33	1	9	9	15	54	55
Mix 7 - core + SERDP RWR	34	1	7	12	6	65	20
Western Yarrow Check	1	2	24	24	24	0	100
Mix 6 - core + SERDP Sib.WG	2	2	24	21	16	15	60
SERDP Slender WG - Rhiz.	3	2	21	24	23	6	80
SERDP Western Yarrow	4	2	24	24	24	0	100
AI Intermediate WG	5	2	7	9	6	69	10
Mix 1 - Introduced	6	2	8	20	14	42	35
SERDP TC-2 Western WG	7	2	11	7	7	65	45
Bannock Thickspike WG	8	2	4	13	8	65	15
SERDP Snake River WG	9	2	18	19	22	18	70
Bozoisky RWR	10	2	21	21	12	25	50
SERDP Syn A RWR	11	2	2	5	0	90	15

Entry	Row	Rep	Number of 24 squares without plants	Number of 24 squares without plants	Number of 24 squares without plants	Percent stand	% Weeds in plots (visual est.)
SERDP Slender WG	12	2	1	5	5	85	15
SERDP Vavilov Siberian WG	13	2	8	12	6	64	5
Roadcrest Crested WG	14	2	21	23	22	8	50
P-7 Bluebunch WG	15	2	10	12	3	65	30
Vavilov Siberian WG	16	2	9	11	2	69	1
Mix 2 - Native	17	2	9	6	8	68	40
Secar Snake River WG	18	2	17	23	24	11	75
Rosana Western WG	19	2	2	1	3	92	35
Kazak Pub. Siberian WG	20	2	6	3	3	83	45
Mix 4 - core native	21	2	14	4	11	60	65
SB-2 Western WG	22	2	5	11	9	65	45
SERDP Basin WR	23	2	23	20	23	8	75
Pryor Slender WG	24	2	6	3	1	86	10
Lovington Blue Grama	25	2	21	19	24	11	90
Mix 7 - core + SERDP RWR	26	2	6	3	6	79	10
Mix 3 - Guernsey	27	2	3	13	15	57	35
Bozoisky X Tetra RWR	28	2	5	5	7	76	10
Trailhead Basin WR	29	2	22	22	22	8	75
Texoka Buffalo Grass	30	2	16	19	23	19	90
Goldar Bluebunch WG	31	2	11	14	10	51	40
Flintlock Western WG	32	2	6	9	4	74	60
Mix 5 - core + AI IWG	33	2	4	3	4	85	5
Camper Little Bluestem	34	2	24	24	24	0	80
Pryor Slender WG	1	3	20	20	19	18	65
SERDP Snake River WG	2	3	24	24	24	0	90
SERDP Basin WR	3	3	24	24	24	0	90
Bozoisky RWR	4	3	17	20	10	35	90
Bannock Thickspike WG	5	3	12	13	9	53	70
Mix 3 - Guernsey	6	3	19	17	16	28	65
SB-2 Western WG	7	3	12	12	20	39	60
Vavilov Siberian WG	8	3	3	13	7	68	1
AI Intermediate WG	9	3	2	4	5	85	5
Western Yarrow Check	10	3	24	24	24	0	80
Mix 1 - Introduced	11	3	5	6	5	78	5

Entry	Row	Rep	Number of 24 squares without plants	Number of 24 squares without plants	Number of 24 squares without plants	Percent stand	% Weeds in plots (visual est.)
Bozoisky X Tetra RWR	12	3	7	2	7	78	5
SERDP TC-2 Western WG	13	3	4	11	6	71	25
Kazak Pub. Siberian WG	14	3	7	10	8	65	25
SERDP Slender WG - Rhiz.	15	3	22	20	18	17	60
SERDP Vavilov Siberian WG	16	3	8	7	0	79	0
Mix 7 - core + SERDP RWR	17	3	10	4	8	69	20
Rosana Western WG	18	3	7	7	8	69	25
Flintlock Western WG	19	3	14	5	13	56	40
P-7 Bluebunch WG	20	3	7	5	11	68	30
Roadcrest Crested WG	21	3	15	13	21	32	50
Mix 5 - core + Al IWG	22	3	4	5	2	85	15
Goldar Bluebunch WG	23	3	18	2	14	53	30
Camper Little Bluestem	24	3	24	24	24	0	80
Mix 2 - Native	25	3	3	6	6	79	30
Secar Snake River WG	26	3	21	22	21	11	75
Trailhead Basin WR	27	3	22	22	24	6	85
SERDP Western Yarrow	28	3	24	24	24	0	90
Mix 6 - core + SERDP Sib.WG	29	3	11	4	4	74	5
Lovington Blue Grama	30	3	24	24	24	0	80
Texoka Buffalo Grass	31	3	22	24	16	14	85
Mix 4 - core native	32	3	5	9	6	72	10
SERDP Syn A RWR	33	3	10	4	5	74	5
SERDP Slender WG	34	3	3	15	13	57	15

Table 47. Guernsey River site 2-year percent stand, weed, litter, and bare ground data taken June 2006 (visual ratings).

Entry	Row	Rep	% ground cover planted species	% weeds	% litter	% bare ground
AI Intermediate WG	25	1	48.33	0.00	26.67	25.00
AI Intermediate WG	5	2	33.33	1.67	18.33	46.67
AI Intermediate WG	9	3	46.67	0.00	21.67	31.67
Bannock Thickspike WG	29	1	21.67	6.67	41.67	30.00
Bannock Thickspike WG	8	2	46.67	0.00	16.67	36.67
Bannock Thickspike WG	5	3	31.67	5.00	15.00	48.33
Bozoisky RWR	2	1	26.67	3.67	15.00	54.67
Bozoisky RWR	10	2	26.67	0.00	28.33	45.00
Bozoisky RWR	4	3	20.00	8.33	18.33	53.33
Bozoisky X Tetra RWR	1	1	31.67	0.00	40.00	28.33
Bozoisky X Tetra RWR	28	2	26.67	0.00	28.33	45.00
Bozoisky X Tetra RWR	12	3	33.33	0.00	30.00	36.67
Camper Little Bluestem	31	1	0.00	26.67	36.67	36.67
Camper Little Bluestem	34	2	0.00	25.00	23.33	51.67
Camper Little Bluestem	24	3	3.33	48.33	28.33	20.00
Flintlock Western WG	15	1	10.00	3.67	30.00	56.33
Flintlock Western WG	32	2	25.00	20.00	16.67	38.33
Flintlock Western WG	19	3	38.33	0.00	20.00	41.67
Goldar Bluebunch WG	11	1	16.67	3.33	11.67	68.33
Goldar Bluebunch WG	31	2	20.00	13.33	21.67	45.00
Goldar Bluebunch WG	23	3	36.67	3.33	23.33	36.67
Kazak Pub. Siberian WG	8	1	33.33	0.00	31.67	35.00
Kazak Pub. Siberian WG	20	2	35.00	0.00	30.00	35.00
Kazak Pub. Siberian WG	14	3	41.67	0.00	16.67	41.67
Lovington Blue Grama	27	1	0.00	33.33	40.00	26.67
Lovington Blue Grama	25	2	1.67	26.67	31.67	40.00
Lovington Blue Grama	30	3	0.00	36.67	26.67	36.67
Mix 1 - Introduced	23	1	41.67	0.00	38.33	20.00
Mix 1 - Introduced	6	2	43.33	0.00	13.33	43.33

Entry	Row	Rep	% ground cover planted species	% weeds	% litter	% bare ground
Mix 1 - Introduced	11	3	45.00	0.00	21.67	33.33
Mix 2 - Native	24	1	26.67	3.33	46.67	23.33
Mix 2 - Native	17	2	38.33	6.67	16.67	38.33
Mix 2 - Native	25	3	36.67	5.00	25.00	33.33
Mix 3 - Guernsey	26	1	33.33	0.00	28.33	38.33
Mix 3 - Guernsey	27	2	31.67	1.67	21.67	45.00
Mix 3 - Guernsey	6	3	13.33	5.00	13.33	68.33
Mix 4 - core native	28	1	23.33	5.00	38.33	33.33
Mix 4 - core native	21	2	35.00	6.67	18.33	40.00
Mix 4 - core native	32	3	51.67	0.00	16.67	31.67
Mix 5 - core + Al IWG	30	1	38.33	10.00	26.67	25.00
Mix 5 - core + Al IWG	33	2	45.00	1.67	11.67	41.67
Mix 5 - core + Al IWG	22	3	38.33	0.00	21.67	40.00
Mix 6 - core + SERDP Sib.WG	32	1	31.67	1.67	33.33	33.33
Mix 6 - core + SERDP Sib.WG	2	2	13.33	38.33	20.00	28.33
Mix 6 - core + SERDP Sib.WG	29	3	33.33	1.67	21.67	43.33
Mix 7 - core + SERDP RWR	34	1	25.00	3.33	21.67	50.00
Mix 7 - core + SERDP RWR	26	2	40.00	0.00	21.67	34.70
Mix 7 - core + SERDP RWR	17	3	40.00	1.67	18.33	40.00
P-7 Bluebunch WG	12	1	6.67	11.67	36.67	45.00
P-7 Bluebunch WG	15	2	38.33	1.67	20.00	40.00
P-7 Bluebunch WG	20	3	40.00	1.67	21.67	36.67
Pryor Slender WG	4	1	8.33	6.67	46.67	38.33
Pryor Slender WG	24	2	26.67	3.33	25.00	45.00
Pryor Slender WG	1	3	8.33	48.33	23.33	20.00
Roadcrest Crested WG	7	1	0.00	25.00	50.00	25.00
Roadcrest Crested WG	14	2	31.67	1.67	28.33	38.33
Roadcrest Crested WG	21	3	21.67	0.33	15.00	63.00
Rosana Western WG	17	1	40.00	1.67	21.67	36.67
Rosana Western WG	19	2	35.00	0.00	31.00	34.00
Rosana Western WG	18	3	45.00	0.33	23.33	31.33

Entry	Row	Rep	% ground cover planted species	% weeds	% litter	% bare ground
SB-2 Western WG	16	1	30.00	11.67	21.67	36.67
SB-2 Western WG	22	2	20.00	1.67	21.67	56.67
SB-2 Western WG	7	3	16.67	6.67	18.33	58.33
Secar Snake River WG	13	1	1.67	21.67	40.00	36.67
Secar Snake River WG	18	2	20.00	5.00	35.00	40.00
Secar Snake River WG	26	3	21.67	11.67	20.00	46.67
SERDP Basin WR	20	1	8.33	25.00	25.00	41.67
SERDP Basin WR	23	2	0.00	20.00	20.00	60.00
SERDP Basin WR	3	3	0.00	43.33	21.67	35.00
SERDP Slender WG	5	1	53.33	0.00	16.67	30.00
SERDP Slender WG	12	2	31.67	0.00	15.00	53.33
SERDP Slender WG	34	3	26.67	3.33	25.00	45.00
SERDP Slender WG - Rhiz.	6	1	8.33	20.00	43.33	28.33
SERDP Slender WG - Rhiz.	3	2	6.67	36.67	15.00	41.67
SERDP Slender WG - Rhiz.	15	3	8.33	6.67	21.67	63.33
SERDP Snake River WG	14	1	0.00	21.67	48.33	30.00
SERDP Snake River WG	9	2	20.00	5.00	15.00	60.00
SERDP Snake River WG	2	3	1.67	50.00	16.67	31.67
SERDP Syn A RWR	3	1	30.00	0.33	23.33	46.33
SERDP Syn A RWR	11	2	46.67	0.00	30.00	23.33
SERDP Syn A RWR	33	3	35.00	0.00	30.00	35.00
SERDP TC-2 Western WG	18	1	56.67	0.00	23.33	20.00
SERDP TC-2 Western WG	7	2	38.33	1.67	25.00	35.00
SERDP TC-2 Western WG	13	3	38.33	1.67	21.67	38.33
SERDP Vavilov Siberian WG	10	1	36.67	0.00	18.33	45.00
SERDP Vavilov Siberian WG	13	2	41.67	0.00	20.00	38.33
SERDP Vavilov Siberian WG	16	3	43.33	1.67	21.67	33.33
SERDP Western Yarrow	22	1	0.00	23.33	46.67	30.00
SERDP Western Yarrow	4	2	0.00	46.67	15.00	38.33
SERDP Western Yarrow	28	3	0.00	35.00	35.00	30.00
Texoka Buffalo Grass	33	1	48.33	1.67	21.67	28.33

Entry	Row	Rep	% ground cover planted species	% weeds	% litter	% bare ground
Texoka Buffalo Grass	30	2	20.00	13.33	43.33	23.33
Texoka Buffalo Grass	31	3	25.00	26.67	25.00	23.33
Trailhead Basin WR	19	1	21.67	15.33	20.00	43.00
Trailhead Basin WR	29	2	5.00	45.00	30.00	20.00
Trailhead Basin WR	27	3	13.33	25.00	25.00	36.67
Vavilov Siberian WG	9	1	50.00	1.67	18.33	30.00
Vavilov Siberian WG	16	2	28.33	0.00	11.67	60.00
Vavilov Siberian WG	8	3	36.67	0.00	16.67	46.67
Western Yarrow Check	21	1	0.00	33.33	33.33	33.33
Western Yarrow Check	1	2	0.00	33.33	30.00	36.67
Western Yarrow Check	10	3	0.00	40.00	28.33	31.67

The **Guernsey Tower site** was planted 23 March 2005 (Table 48). Establishment data were taken 2 months later on 2 June 2005 (Table 49). Coverage data were taken 1 year later in June 2006 (Table 50); no data were taken in 2007 because of drought conditions.

Table 48. Camp Guernsey Tower site monoculture 2-month establishment data taken 2 June 2005 (48-grid frame; 6.35 x 6.35 cm squares).

Entry	Row	Rep	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Percent stand	Average percent stand by entry
P-7 Bluebunch WG	12	1	11	14	10	76	56
P-7 Bluebunch WG	15	2	27	30	43	31	
P-7 Bluebunch WG	20	3	30	9	17	61	
Goldar Bluebunch WG	11	1	16	19	16	65	55
Goldar Bluebunch WG	31	2	10	23	28	58	
Goldar Bluebunch WG	23	3	26	21	35	43	
SERDP Basin WR	20	1	19	31	34	42	40
SERDP Basin WR	23	2	37	37	34	25	
SERDP Basin WR	3	3	27	28	13	53	

Entry	Row	Rep	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Percent stand	Average percent stand by entry
Trailhead Basin WR	19	1	26	35	40	30	50
Trailhead Basin WR	29	2	11	6	8	83	
Trailhead Basin WR	27	3	22	41	25	39	
SERDP Syn A RWR	3	1	23	22	10	62	50
SERDP Syn A RWR	11	2	20	30	13	56	
SERDP Syn A RWR	33	3	35	36	26	33	
Bozoisky RWR	2	1	18	6	17	72	65
Bozoisky RWR	10	2	23	24	19	54	
Bozoisky RWR	4	3	18	15	11	69	
Pryor Slender WG	4	1	19	18	29	54	37
Pryor Slender WG	24	2	34	42	38	21	
Pryor Slender WG	1	3	39	26	28	35	
SERDP Slender WG	5	1	10	28	14	64	62
SERDP Slender WG	12	2	18	21	17	61	
SERDP Slender WG	34	3	16	24	17	60	
Secar Snake River WG	13	1	22	28	16	54	44
Secar Snake River WG	18	2	27	23	31	44	
Secar Snake River WG	26	3	24	38	35	33	
SERDP Snake River WG	14	1	27	19	28	49	55
SERDP Snake River WG	9	2	38	24	33	34	
SERDP Snake River WG	2	3	9	6	12	81	
SERDP Vavilov Siberian WG	10	1	21	10	9	72	68
SERDP Vavilov Siberian WG	13	2	13	19	21	63	
SERDP Vavilov Siberian WG	16	3	19	19	9	67	
Vavilov Siberian WG	9	1	17	9	16	71	65
Vavilov Siberian WG	16	2	30	20	17	53	
Vavilov Siberian WG	8	3	21	16	4	72	
Rosana Western WG	17	1	21	39	31	37	39
Rosana Western WG	19	2	39	29	25	35	
Rosana Western WG	18	3	23	30	26	45	

Entry	Row	Rep	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Percent stand	Average percent stand by entry
SERDP TC-2 Western WG	18	1	27	25	40	36	51
SERDP TC-2 Western WG	7	2	25	27	19	51	
SERDP TC-2 Western WG	13	3	21	16	12	66	
SERDP Western Yarrow	22	1	48	48	48	0	0
SERDP Western Yarrow	4	2	48	48	48	0	
SERDP Western Yarrow	28	3	47	48	48	1	
Western Yarrow Check	21	1	48	48	48	0	0
Western Yarrow Check	1	2	48	48	48	0	
Western Yarrow Check	10	3	48	48	48	0	

Table 49. Guernsey Tower site mix 2-month establishment data taken 2 June 2005 (48-grid frame with 6.35 x 6.35 cm squares).

Entry	Row	Rep	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Percent stand
Mix 1 - Introduced	23	1	24	26	28	46
Mix 1 - Introduced	6	2	24	25	20	52
Mix 1 - Introduced	11	3	14	14	11	73
Mix 2 - Native	24	1	19	22	23	56
Mix 2 - Native	17	2	32	24	19	48
Mix 2 - Native	25	3	27	27	23	47
Mix 3 - Guernsey	26	1	33	36	40	24
Mix 3 - Guernsey	27	2	24	40	40	28
Mix 3 - Guernsey	6	3	41	31	37	24
Mix 4 - core native	28	1	21	16	32	52
Mix 4 - core native	21	2	18	23	29	51
Mix 4 - core native	32	3	21	41	30	36
Mix 5 - core + AI IWG	30	1	26	35	25	40

Entry	Row	Rep	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Number of squares without plants (out of 48)	Percent stand
Mix 5 - core + AI IWG	33	2	24	35	19	46
Mix 5 - core + AI IWG	22	3	36	19	32	40
Mix 6 - core + SERDP Sib.WG	32	1	37	39	21	33
Mix 6 - core + SERDP Sib.WG	2	2	24	19	16	59
Mix 6 - core + SERDP Sib.WG	29	3	31	25	30	40
Mix 7 - core + SERDP RWR	34	1	44	32	45	16
Mix 7 - core + SERDP RWR	26	2	6	26	24	61
Mix 7 - core + SERDP RWR	17	3	10	23	27	58

Table 50. Guernsey Tower site 1-year percent stand, weed, litter, and bare ground data taken June 2006 (visual ratings).

Entry	Row	Rep	As percentage (%)			
			Ground cover planted species	Weeds	Litter	Bare ground
AI Intermediate WG	25	1	15.00	9.00	16.67	59.33
AI Intermediate WG	5	2	20.00	2.33	21.67	56.00
AI Intermediate WG	9	3	21.67	0.00	8.67	69.67
Bannock Thickspike WG	29	1	18.33	4.00	18.33	59.33
Bannock Thickspike WG	8	2	11.67	7.33	33.33	47.67
Bannock Thickspike WG	5	3	20.00	2.33	8.33	69.33
Bozoisky RWR	2	1	28.33	0.33	25.00	46.33
Bozoisky RWR	10	2	11.67	2.00	20.00	66.33
Bozoisky RWR	4	3	13.33	1.67	15.00	70.00
Bozoisky X Tetra RWR	1	1	28.33	0.00	18.33	53.33
Bozoisky X Tetra RWR	28	2	16.67	2.00	8.33	73.00
Bozoisky X Tetra RWR	12	3	8.33	0.00	20.00	1.30
Camper Little Bluestem	31	1	13.33	13.33	18.33	55.00
Camper Little Bluestem	34	2	0.00	20.33	11.67	68.00
Camper Little Bluestem	24	3	3.33	21.67	18.33	56.67
Flintlock Western WG	15	1	10.00	11.67	25.00	53.33
Flintlock Western WG	32	2	3.33	10.00	7.00	79.67
Flintlock Western WG	19	3	20.00	10.67	15.00	54.33
Goldar Bluebunch WG	11	1	31.67	5.00	11.67	51.67
Goldar Bluebunch WG	31	2	16.67	0.67	13.33	69.33
Goldar Bluebunch WG	23	3	13.33	1.60	17.00	4.38
Kazak Pub. Siberian WG	8	1	23.33	5.33	20.00	51.33
Kazak Pub. Siberian WG	20	2	23.33	3.33	12.00	61.33
Kazak Pub. Siberian WG	14	3	18.33	2.00	11.67	3.40
Lovington Blue Grama	27	1	8.33	15.00	28.33	48.33
Lovington Blue Grama	25	2	0.33	15.00	11.67	73.00
Lovington Blue Grama	30	3	0.00	16.67	15.00	68.33
Mix 1 - Introduced	23	1	25.00	2.33	15.00	57.67
Mix 1 - Introduced	6	2	38.33	5.00	15.00	41.67

Entry	Row	Rep	As percentage (%)			
			Ground cover planted species	Weeds	Litter	Bare ground
Mix 1 - Introduced	11	3	21.67	3.33	13.33	61.67
Mix 2 - Native	24	1	15.00	10.00	16.67	58.33
Mix 2 - Native	17	2	25.00	0.67	11.67	62.67
Mix 2 - Native	25	3	16.67	5.00	18.33	5.44
Mix 3 - Guernsey	26	1	15.00	5.00	20.00	60.00
Mix 3 - Guernsey	27	2	10.00	5.00	8.67	76.33
Mix 3 - Guernsey	6	3	3.33	5.33	13.33	78.00
Mix 4 - core native	28	1	31.67	4.00	23.33	41.00
Mix 4 - core native	21	2	21.67	3.67	16.67	58.00
Mix 4 - core native	32	3	16.67	5.00	15.00	63.33
Mix 5 - core + AI IWG	30	1	25.00	7.00	15.00	53.00
Mix 5 - core + AI IWG	33	2	18.33	0.67	11.67	69.33
Mix 5 - core + AI IWG	22	3	15.00	5.33	12.00	67.67
Mix 6 - core + SERDP Sib.WG	32	1	20.00	6.67	25.00	48.33
Mix 6 - core + SERDP Sib.WG	2	2	20.00	5.00	13.33	61.67
Mix 6 - core + SERDP Sib.WG	29	3	31.67	0.33	16.67	51.33
Mix 7 - core + SERDP RWR	34	1	8.33	13.33	16.67	61.67
Mix 7 - core + SERDP RWR	26	2	25.00	3.67	10.00	61.33
Mix 7 - core + SERDP RWR	17	3	16.67	3.67	11.67	68.00
P-7 Bluebunch WG	12	1	25.00	3.67	11.67	59.67
P-7 Bluebunch WG	15	2	25.00	3.67	10.33	61.00
P-7 Bluebunch WG	20	3	25.00	0.33	10.00	64.67
Pryor Slender WG	4	1	41.67	2.00	21.67	34.67
Pryor Slender WG	24	2	26.67	5.67	11.67	56.00
Pryor Slender WG	1	3	28.33	3.67	6.67	61.33
Roadcrest Crested WG	7	1	21.67	3.33	18.33	56.67
Roadcrest Crested WG	14	2	20.00	3.67	15.00	61.33
Roadcrest Crested WG	21	3	13.33	1.60	13.33	4.88
Rosana Western WG	17	1	26.67	3.67	10.00	59.67
Rosana Western WG	19	2	26.67	2.00	26.67	44.67

Entry	Row	Rep	As percentage (%)			
			Ground cover planted species	Weeds	Litter	Bare ground
Rosana Western WG	18	3	15.00	3.33	13.33	68.33
SB-2 Western WG	16	1	28.33	5.00	11.67	55.00
SB-2 Western WG	22	2	11.67	5.33	23.33	59.67
SB-2 Western WG	7	3	15.00	5.33	11.67	68.00
Secar Snake River WG	13	1	23.33	5.00	16.67	55.00
Secar Snake River WG	18	2	20.00	3.67	11.67	64.67
Secar Snake River WG	26	3	13.33	10.00	13.33	63.33
SERDP Basin WR	20	1	0.00	20.00	28.33	51.67
SERDP Basin WR	23	2	3.33	16.67	15.00	65.00
SERDP Basin WR	3	3	5.00	6.60	10.00	1.00
SERDP Slender WG	5	1	46.67	0.00	18.33	35.00
SERDP Slender WG	12	2	26.67	4.00	13.33	56.00
SERDP Slender WG	34	3	41.67	0.00	11.67	46.67
SERDP Slender WG - Rhiz.	6	1	31.67	3.67	43.33	21.33
SERDP Slender WG - Rhiz.	3	2	13.33	3.67	36.67	46.33
SERDP Slender WG - Rhiz.	15	3	15.00	8.33	18.33	58.33
SERDP Snake River WG	14	1	21.67	3.33	23.33	51.67
SERDP Snake River WG	9	2	20.00	6.67	21.67	51.67
SERDP Snake River WG	2	3	13.33	1.67	10.00	75.00
SERDP Syn A RWR	3	1	30.00	1.67	38.33	30.00
SERDP Syn A RWR	11	2	13.33	5.33	13.33	68.00
SERDP Syn A RWR	33	3	25.00	3.33	11.67	60.00
SERDP TC-2 Western WG	18	1	21.67	8.33	16.67	53.33
SERDP TC-2 Western WG	7	2	10.00	7.00	16.67	66.33
SERDP TC-2 Western WG	13	3	15.00	7.00	10.00	68.00
SERDP Vavilov Siberian WG	10	1	33.33	5.33	11.67	49.67
SERDP Vavilov Siberian WG	13	2	16.67	3.33	11.67	68.33
SERDP Vavilov Siberian WG	16	3	21.67	2.00	13.33	63.00
SERDP Western Yarrow	22	1	0.00	20.00	20.00	60.00
SERDP Western Yarrow	4	2	0.00	25.00	8.33	66.67

Entry	Row	Rep	As percentage (%)			
			Ground cover planted species	Weeds	Litter	Bare ground
SERDP Western Yarrow	28	3	3.33	20.00	11.67	65.00
Texoka Buffalo Grass	33	1	18.33	10.00	11.67	60.00
Texoka Buffalo Grass	30	2	26.67	10.33	8.67	54.33
Texoka Buffalo Grass	31	3	16.67	11.67	16.67	55.00
Trailhead Basin WR	19	1	0.00	25.00	15.00	60.00
Trailhead Basin WR	29	2	18.33	4.00	18.33	59.33
Trailhead Basin WR	27	3	0.00	0.00	0.00	0.00
Vavilov Siberian WG	9	1	23.33	5.33	10.00	61.33
Vavilov Siberian WG	16	2	18.33	2.00	17.00	62.67
Vavilov Siberian WG	8	3	16.67	0.33	10.00	73.00
Western Yarrow Check	21	1	0.00	13.33	13.33	73.33
Western Yarrow Check	1	2	5.00	31.67	11.67	51.67
Western Yarrow Check	10	3	0.00	20.00	10.33	69.67

D.7 Fort Drum data (mixtures)

The 4 years of data (2003-2006) from the Fort Drum airport site are shown below in Table 51 – Table 54.

Table 51. Fort Drum Airport site 1-year percent cover and bare ground on 24 June 2003.

	Treatment	WL	FF	SG	HG	Total sown species	Other species	Dead WL	Bare ground
1	Weeping lovegrass	53	--	--	--	53	15	32	0
2	Weeping lovegrass + hairgrass	79	--	--	0	79	5	12	4
3	Weeping lovegrass + switchgrass	8	--	42	--	49	24	23	4
4	Weeping lovegrass + switchgrass + hairgrass	42	--	14	0	56	11	28	5
5	Weeping lovegrass + hairgrass + switchgrass + fine fescues	31	21	3	0	55	3	19	2
6	Weeping lovegrass + hairgrasses + fine fescues	35	9	--	0	45	11	18	27
7	Weeping lovegrass + switchgrass + fine fescues	13	19	43	--	75	11	7	9
8	Weeping lovegrass + fine fescues	24	36	--	--	60	18	18	5
	LSD @ 0.05	32	20	18	ns	ns	ns	ns	ns

Table 52. Fort Drum Airport site 2-year percent cover and bare ground on 29 June 2004.

	Treatment	WL	FF	SG	HG	Total sown species	Other species	Dead WL	Bare ground
1	Weeping lovegrass	2	-	-	-	2	61	24	14
2	Weeping lovegrass + hairgrass	1	-	-	0	12	46	30	13
3	Weeping lovegrass + switchgrass	0	-	48	-	37	41	13	9
4	Weeping lovegrass + switchgrass + hairgrass	3	-	39	0	42	28	16	13
5	Weeping lovegrass + hairgrass + switchgrass + fine fescues	0	34	13	0	48	27	14	10
6	Weeping lovegrass + hairgrasses + fine fescues	0	26	-	0	19	42	22	16
7	Weeping lovegrass + switchgrass + fine fescues	0	16	37	-	60	16	7	17
8	Weeping lovegrass + fine fescues	8	57	-	-	22	29	26	23
	LSD @ 0.05	ns	23	20	ns	25	ns	19	19

Table 53. Fort Drum Airport site 3-year percent cover and bare ground on 7 September 2005.

	Treatment	WL	FF	SG	HG	Total sown species	Other species	Dead WL	Bare ground
1	Weeping lovegrass	8	-	-	-	8	22	14	56
2	Weeping lovegrass + hairgrass	0	-	-	0	0	25	48	27
3	Weeping lovegrass + switchgrass	1	-	46	-	48	5	1	46
4	Weeping lovegrass + switchgrass + hairgrass	0	-	50	0	51	6	2	40
5	Weeping lovegrass + hairgrass + switchgrass + fine fescues	0	31	17	0	48	6	7	39
6	Weeping lovegrass + hairgrasses + fine fescues	1	33	-	0	33	26	1	40
7	Weeping lovegrass + switchgrass + fine fescues	0	44	31	-	76	0	4	21
8	Weeping lovegrass + fine fescues	0	65	-	-	65	1	3	32
	LSD @ 0.05	ns	16	16	ns	19	ns	11	ns

Table 54. Fort Drum Airport site 4-year percent cover and bare ground on 7 June 2006.

	Treatment	WL	FF	SG	HG	Total sown species	Other species	Dead (mostly WL)	Bare ground
1	Weeping lovegrass	0	---	---	---	0	28	18	54
2	Weeping lovegrass + hairgrass	0	---	---	0	0	78	7	15
3	Weeping lovegrass + switchgrass	0	---	64	---	64	7	6	24
4	Weeping lovegrass + switchgrass + hairgrass	0	---	52	0	52	3	24	21
5	Weeping lovegrass + hairgrass + switchgrass + fine fescues	0	38	0	0	38	24	3	34
6	Weeping lovegrass + hairgrasses + fine fescues	0	39	---	0	39	24	2	34
7	Weeping lovegrass + switchgrass + fine fescues	0	33	24	---	57	0	3	33
8	Weeping lovegrass + fine fescues	0	43	---	---	43	6	0	51
	LSD @ 0.05	ns	ns	8	ns	16	21	14	18

D.8 Tracking data

The 2005 soil data by entry immediately before and after tracking are shown below (Table 55 – Table 59); summary soil data are given in Section 5.6.3.1. There were essentially no significant differences in soil data among the different plant entries. The only significant difference was between the two Snake River wheatgrass entries for shear vane measurements before tracking.

Table 55. Soil moisture, shear vane, and cone penetrometer data immediately before and after tracking (June 2005).

Entry	Before tracking		Cone penetrometer (cm) (after tracking)		
	Soil moisture (%)	Shear vane (kPa)	0 Pass	1 Pass	4 Pass
Siberian wheatgrass (Vavilov II)	2.9	43.8	6.2	7.3	10.5
Siberian wheatgrass (Vavilov)	3.0	38.9	5.5	7.7	12.1
Russian wildrye (Bozoisky II parent)	2.7	36.2	6.3	8.2	11.4
Russian wildrye (BozXTet)	3.0	39.2	6.1	7.0	11.6
Crested wheatgrass (Roadcrest)	2.8	37.9	6.7	6.8	10.5
Basin wheatgrass (Trailhead)	2.9	41.5	6.5	7.9	12.6
Mix-1-Introduced	2.8	45.2	6.7	8.3	11.1
Mix-2-Native	2.6	36.2	6.8	6.9	10.6
Bluebunch wheatgrass (P7)	3.1	39.0	5.3	8.3	12.1
Bluebunch wheatgrass (Goldar)	3.0	40.2	7.0	7.6	12.2
Sandberg wheatgrass (Reliable)	2.8	34.5	6.3	7.8	11.7
Sandberg wheatgrass (common variety)	2.7	36.8	5.4	8.0	12.0
Slender wheatgrass (FirstStrike)	2.9	36.3	6.0	7.8	12.0
Slender wheatgrass (Pryor)	2.7	35.0	5.9	8.9	12.6
Snake River wheatgrass (SERDP Select)	2.6	48.7*	7.2	7.2	12.0
Snake River wheatgrass (Secar)	2.8	34.9	7.2	9.0	12.2
Western wheatgrass (Recovery)	2.8	35.7	5.9	8.2	11.0
Western wheatgrass (Rosana)	2.6	38.5	5.9	7.6	11.9
Western Yarrow (Yakima)	2.9	38.4	6.2	7.7	11.5
Western Yarrow (common variety)	2.9	39.8	6.2	8.0	12.3
Overall mean	2.8	38.8	6.3	7.8	11.6
LSD @0.05	0.3	6.5	ns	ns	ns

* Significantly different than the standard cultivar entry for this species.

Table 56. Rut depth means by entry for all years after tracking (2005-2007).

Entry	Rut depth (cm)		
	1 Pass	4 Pass	LSD @ 0.05
Siberian wheatgrass (Vavilov II)	3.25	5.33	1.85
Siberian wheatgrass (Vavilov)	4.75	7.23	0.83
Russian wildrye (Bozoisky II parent)	4.25	6.62	0.49
Russian wildrye (BozXTet)	4.25	7.29	1.47
Slender wheatgrass (FirstStrike)	4	7.42	2.49
Slender wheatgrass (Pryor)	5.75	8.47	0.86
Snake River wheatgrass (SERDP Select)	4.04	8.92	1.63
Snake River wheatgrass (Secar)	4.7	6.76	1.54
Western wheatgrass (Recovery)	3.7	6.01	1.63
Western wheatgrass (Rosana)	3.25	6.52	2.25
LSD @ 0.05	0.225	0.246	
Overall mean	4.2	7	0.4

Table 57. Percent cover of vegetation in June 2005 immediately after tracking.

Entry	0 pass	1 pass	4 pass
Bluebunch wheatgrass (P-7)	47.9	29.2	3.1
Bluebunch wheatgrass (Goldar)	35.4	38.5	8.3
Russian wildrye (Bozoisky II)	71.9*	57.3	34.4
Russian wildrye (BozXTet)	33.3	57.3	17.1
Siberian wheatgrass (Vavilov II)	65.6	66.7*	34.4*
Siberian wheatgrass (Vavilov)	42.7	36.5	5.2
Slender wheatgrass (FirstStrike)	17.7	8.3	0
Slender wheatgrass (Pryor)	8.3	10.4	8.3
Snake River wheatgrass (SERDP)	76.0*	74.0	53.1*
Snake River wheatgrass (Secar)	41.7	46.9	20.8
Western wheatgrass (Recovery)	53.1	44.8	17.1
Western wheatgrass (Rosana)	61.5	36.5	18.8
LSD @ 0.05	32	30	24

* Significantly different than the standard cultivar entry for this species.

Table 58. Percent cover of vegetation in June 2006, 1 year after tracking.

Entry	0 pass	1 pass	4 pass
Bluebunch wheatgrass (P-7)	57.3	45.3	8.3
Bluebunch wheatgrass (Goldar)	50.0	49.0	14.6
Russian wildrye (Bozoisky II)	85.4	71.9	50.0
Russian wildrye (BozXTet)	63.5	67.7	42.7
Siberian wheatgrass (Vavilov II)	81.3	84.4	62.5*
Siberian wheatgrass (Vavilov)	66.7	65.6	20.8
Slender wheatgrass (FirstStrike)	22.9	12.5	1.0
Slender wheatgrass (Pryor)	19.8	16.7	9.4
Snake River wheatgrass (SERDP)	82.3	81.3	59.4*
Snake River wheatgrass (Secar)	59.4	53.1	27.1
Western wheatgrass (Recovery)	69.8	53.1	18.8
Western wheatgrass (Rosana)	67.7	46.9	31.3
LSD @ 0.05	34	32	23

* Significantly different than the standard cultivar entry for this species.

Table 59. Percent cover of vegetation in June 2007, 2 years after tracking.

Entry	0 pass	1 pass	4 pass
Bluebunch wheatgrass (P-7)	52.1	35.4	9.4
Bluebunch wheatgrass (Goldar)	27.1	28.1	15.6
Russian wildrye (Bozoisky II)	71.9	71.9*	42.7
Russian wildrye (BozXTet)	59.4	41.7	46.9
Siberian wheatgrass (Vavilov II)	76.0	75.0	65.6*
Siberian wheatgrass (Vavilov)	54.2	56.3	20.8
Slender wheatgrass (FirstStrike)	54.2*	16.7	1.4
Slender wheatgrass (Pryor)	11.5	6.3	5.2
Snake River wheatgrass (SERDP)	69.8	69.8	58.3
Snake River wheatgrass (Secar)	49.0	40.6	38.5
Western wheatgrass (Recovery)	58.3	45.8	21.9
Western wheatgrass (Rosana)	55.2	50.0	40.6
LSD @ 0.05	32	30	27

* Significantly different than the standard cultivar entry for this species.

D.9 Space-planted nursery data

Recovery western wheatgrass

Table 60. Establishment year stand of 'Recovery' western wheatgrass compared with standard western wheatgrass and other rangeland grass checks at 8 locations. Stand establishment measured as seedling frequency during the first May or June following a late-fall-dormant or early-spring planting. (Waldron et al. in prep).

Cultivar†	Beaver, UT	Guernsey, WY – site 1	Guernsey, WY – site 2	Malta, ID	Fillmore, UT – site 1	Fillmore, UT – site 2	Curlew Valley, ID	Yakima, WA	Across loc. Mean
Recovery	0.54	0.61	0.51	0.68	0.66	0.63	0.46	0.73	0.60
WWG checks									
Arriba	0.21*	.	.	0.41*	0.54	0.82	0.44	.	0.45*
Barton	0.36*	.	.	0.55*	0.38*	0.64	0.37	.	0.42*
Flintlock	.	0.57	0.22*	.	.	0.84	.	.	0.53*
Rodan	0.25*	.	.	0.55*	0.48*	0.78	0.39	.	0.45*
Rosana	0.51	0.55	0.39	0.45*	0.35*	0.73	0.49	0.40*	0.48*
SB3	0.40*	0.54	0.49	0.69	0.45*	0.88	0.34*	.	0.53*
Other checks									
Bannock	0.73	0.50	0.51	.	.	.	.	.	0.61
Bozoisky	0.72	0.17	0.65	0.61	0.21	0.63	0.56	.	0.50
Bozoisky_II	0.70	0.48	0.50	0.67	0.23	.	0.60	0.54	0.55
FirstStrike	0.84	0.81	0.62	0.86	0.56	0.81	.	0.82	0.75
Hycrest	0.86	.	.	0.92	0.65	.	0.56	.	0.74
Hycrest_II	0.90	.	.	0.94	0.64	0.63	0.72	.	0.73
Vavilov	0.82	0.38	0.65	0.92	0.54	.	0.40	0.23	0.58
Vavilov_II	0.94	0.54	0.67	0.95	0.79	.	0.70	0.52	0.76
WWG mean	0.38	0.57	0.40	0.56	0.48	0.76	0.41	0.56	0.50
Entry Mean	0.62	0.52	0.52	0.71	0.50	0.74	0.50	0.54	0.58
LSD (0.05)	0.13	0.23	0.18	0.12	0.18	0.18	0.12	0.17	0.06

†Designations in this column include: WWG=western wheatgrass; SB3 is a WWG breeding population closely related to Recovery; Bannock is a thickspike wheatgrass; Bozoisky and Bozoisky II are Russian wildryes; FirstStrike is a slender wheatgrass; Hycrest and Hycrest II are crested wheatgrasses; and Vavilov and Vavilov II are Siberian wheatgrasses.

*Western wheatgrass check cultivars with stand frequency significantly ($P < 0.05$) lower than Recovery western wheatgrass.

Table 61. Second-year stand of 'Recovery' western wheatgrass compared with standard western wheatgrass and other rangeland grass checks at eight locations. Stand establishment measured as plant frequency during the second May or June following a late-fall-dormant or early-spring planting. (Waldron et al. in prep).

Cultivar†	Beaver, UT	Guernsey, WY – site 1	Guernsey, WY – site 2	Malta, ID	Fillmore, UT – site 1	Fillmore, UT – site 2	Curlew Valley, ID	Yakima, WA	Across loc. mean
Recovery	0.84	0.73	0.74	0.73	0.91	0.74	0.60	0.81	0.77
WWG checks									
Arriba	0.63*	.	.	0.32*	0.86	0.88	0.59	.	0.63*
Barton	0.72	.	.	0.55*	0.85	0.84	0.57	.	0.68*
Flintlock	.	0.50	0.71	.	.	0.83	.	.	0.66*
Rodan	0.59*	.	.	0.49*	0.87	0.84	0.61	.	0.66*
Rosana	0.81	0.77	0.78	0.32*	0.72*	0.90	0.61	0.53	0.68*
SB3	0.67*	0.46*	0.76	0.66	0.72*	0.89	0.56	.	0.67*
Other checks									
Bannock	0.85	0.58	0.81	.	.	.	.	.	0.73
Bozoisky	0.88	0.26	0.82	0.57	0.42	0.72	0.70	.	0.61
Bozoisky_II	0.87	0.61	0.81	0.79	0.42	.	0.64	0.67	0.70
FirstStrike	0.94	0.65	0.89	0.38	0.83	0.90	.	0.74	0.75
Hycrest	0.91	.	.	0.93	0.88	.	0.77	.	0.87
Hycrest_II	0.91	.	.	0.97	0.86	0.65	0.82	.	0.82
Vavilov	0.92	0.63	0.77	0.91	0.71	.	0.54	0.36	0.71
Vavilov_II	0.99	0.68	0.91	1.00	0.88	.	0.62	0.63	0.83
WWG mean	**0.71**	**0.62**	**0.75**	**0.51**	**0.82**	**0.85**	**0.59**	**0.67**	**0.68**
Entry Mean	**0.82**	**0.59**	**0.80**	**0.66**	**0.76**	**0.82**	**0.64**	**0.62**	**0.72**
LSD (0.05)	**0.17**	**0.25**	**0.14**	**0.18**	**0.16**	**0.17**	**0.19**	**0.32**	**0.06**

†Designations in this column include: WWG=western wheatgrass; SB3 is a WWG breeding population closely related to Recovery; Bannock is a thickspike wheatgrass; Bozoisky and Bozoisky II are Russian wildryes; FirstStrike is a slender wheatgrass; Hycrest and Hycrest II are crested wheatgrasses; and Vavilov and Vavilov II are Siberian wheatgrasses.

*Western wheatgrass check cultivars with stand frequency significantly ($P < 0.05$) lower than Recovery western wheatgrass.

Table 62. Dry matter yield (DMY) of 'Recovery' western wheatgrass compared with standard western wheatgrass and other rangeland grass checks at three locations. Yield at Nephi and Blue Creek, UT evaluated just prior to anthesis in 2008 from 10-spaced-plant plots established in 2005. Yield from Curlew Valley, ID determined in 2006 just prior to anthesis using 1-m² clipped subsamples of plots established in 2002. (Waldron et al. in prep).

Cultivar	kg/10-plants		g/m²
	Nephi, UT	Blue Creek, UT	Curlew Valley, ID
Recovery	2.0	2.7	262
WWG checks			
Arriba	2.6	2.7	360
Barton	2.9**	3.1	285
Flintlock	3.3**	3.0	.
Rodan	3.0**	3.1	341
Rosana	2.9**	2.4	160*
SB3	2.5	2.2	276
Other checks			
Bozoisky	2.3	2.1	330
Bozoisky_II	2.4	2.1	333
FirstStrike	1.3	1.4	.
Hycrest	2.7	2.9	373
Hycrest_II	2.0	1.8	311
Vavilov	2.6	2.4	373
Vavilov_II	3.4	2.4	291
LSD (0.05)	0.7	0.9	100

†Designations in this column include: WWG=western wheatgrass; SB3 is a WWG breeding population closely related to Recovery; Bozoisky and Bozoisky II are Russian wildryes; FirstStrike is a slender wheatgrass; Hycrest and Hycrest II are crested wheatgrasses; and Vavilov and Vavilov II are Siberian wheatgrasses.

*Western wheatgrass check cultivars with DMY significantly ($P < 0.05$) lower than Recovery western wheatgrass.

**Western wheatgrass check cultivars with DMY significantly ($P < 0.05$) higher than Recovery western wheatgrass.

Vavilov II Siberian wheatgrass

Table 63. Vavilov II Siberian wheatgrass stand establishment and persistence at Malta, Idaho, and Fillmore, Utah.

Entry	(% Stand)		
	Establishment yr: 2005	Persistence yr 2: 2006	Persistence comb: 05–06
Malta, Idaho (established fall 2004)			
Vavilov Siberian wheatgrass	92	91	91
Vavilov II Siberian wheatgrass	95	100	97
LSD (0.05)	5	6	6
Fillmore, Utah (established fall 2004)			
Vavilov Siberian wheatgrass	54	71	62
Vavilov II Siberian wheatgrass	79	88	84
LSD (0.05)	17	12	21

* (P<0.05) Significantly better than the cultivar Vavilov Siberian wheatgrass.

Table 64. Vavilov II Siberian wheatgrass establishment and persistence at YTC (established fall 2002).

Entry	(% Stand)			
	Establishment yr: 2003	Persistence yr 2: 2004	Persistence yr 3: 2005	Persistence comb: 04–05
Vavilov Siberian wheatgrass	23	36	52	44
Vavilov II Siberian wheatgrass	52	63	72	68
LSD (0.05)	16	27	19	22

* (P<0.05) Significantly better than the cultivar Vavilov Siberian wheatgrass.

Table 65. Vavilov II Siberian wheatgrass stand establishment and persistence at Curlew Valley, Idaho (established fall 2002).

Entry	(% Stand)				
	Establish. yr: 2003	Persistence yr 2: 2004	Persistence yr 3: 2005	Persistence yr 4: 2006	Persistence comb: 03–06
Vavilov Siberian wheatgrass	40	54	65	64	55
Vavilov II Siberian wheatgrass	70	62	77	69	69
LSD (0.05)	12	17	14	16	9

* (P<0.05) Significantly better than the cultivar Vavilov Siberian wheatgrass.

Table 66. Vavilov II Siberian wheatgrass establishment and persistence at Camp Guernsey.

Entry	River site			Tower site
	Establishment yr: 2004 (% stand)	Persistence Yr-2: 2005 (% stand)	Persistence comb: 04-05 (% stand)	Establishment yr: 2005 (% stand)†
Vavilov Siberian wheatgrass	38	63	50	65
Vavilov II Siberian wheatgrass	54	68	61	67
LSD (0.05)	20	25	19	22

Table 67. Vavilov II Siberian wheatgrass dry matter yield at YTC and Camp Guernsey in 2005.

Entry	DM yield‡ (g)		
	Guernsey, WY	Yakima, WA	Comb. loc.
Vavilov Siberian WG	52	29	39
Vavilov II Siberian WG	79	33	53
LSD (0.05)	18	9	11

* (P<0.05) Significantly better than the cultivar Vavilov Siberian wheatgrass.

‡ DM yield (64 x 38 cm plot - average of three plots)

Bozoisky II Russian wildrye

Table 68. Bozoisky II Russian wildrye percent stand establishment in 2001 in Northern Area Plains Regional Trials (NPA) established fall 1999 (Jensen et al. 2006).

Entry	% Stand						
	Blue Creek, UT	Green Canyon, UT	Mead, NE	Mandan, ND	Miles City, MT	Sidney, NE	Combined locations
Diploids							
Bozoisky-II	55	60	98	85	79	72	76
Bozoisky-Select	41	42	99	79	75	71	69
Mankota	46	51	100	84	93	80	76
Tetraploids							
Tetracan	59	65	77	65*	89	73	71
Tetra-1 RWR	58	57	99	78	97	68	76
BozXTet	71	62	100	67*	97	80	79
LSD (0.05)	17	19	ns	18	17	24	13
Test Mean	56	68	96	76	80	73	75
Test High	78	100	100	99	97	100	95
Test Low	8	32	62	39	48	28	21
No. Entries	91	91	86	88	88	82	98

* Entries significantly less than Bozoisky-II (P<0.05)

Table 69. Bozoisky II Russian wildrye percent stand establishment at three additional sites (Jensen et al. 2006).

Entry	Gurnsey, WY (est. 3/04) 2004	Curlew Valley, ID (est. 11/02) 2003	YTC (est. 11/02) 2003
Diploids			
Bozoisky-II	48	60	54
Bozoisky-Select	17*	56	__
Mankota	__	__	__
Swift	__	__	__
Tetraploids			
BozXTet	59	45*	47
Tetra-1	__	__	__
Tetracan	__		
LSD (0.05)	19	12	16
Test Mean	37	55	36
Test Min.	0	34	4
Test Max	81	81	82
No. of Entries	34	23	20

* Significantly less than Bozoisky-II (P<0.05)

Table 70. Bozoisky II Russian wildrye persistence as measured by percent stand in 2003 at four NPA sites, established 1999 (Jensen et al. 2006).

Entry	% Stand				
	Mead, NE	Mandan, ND	Miles City, MT	Sidney, NE	Combined locations
Diploids					
Bozoisky-II	100	93	70	74	85
Bozoisky-Select	98	87	75	83	86
Mankota	100	93	81	78	88
Tetraploids					
Tetracan	78*	82	67	78	77
Tetra-1 RWR	100	86	73	76	84
BozXTet	100	80	83	80	86
LSD (0.05)	17	14	24	24	13
Test Mean	75	84	34	73	67
Test High	100	100	83	100	96
Test Low	5	22	1	28	14
No. Entries	86	86	88	82	86

Significantly less than Bozoisky-II (P<0.05)

Table 71.Bozoisky II Russian wildrye dry matter forage yield at NPA trial sites (established fall 1999).

Cultivar	Blue Creek, UT	Green Canyon, UT	Mead, NE	Mandan, ND	Miles City, MT	Sidney, NE	Combined locations
	kg/ha dry matter yield						
	2001–03	2001–03	2001–03	2001–03	2001–03	2001–03	2001–03
Diploids							
Bozoisky-II	402	1096	4592	2767	1818	3600	2675
Bozoisky-Select	565	785	4464	2678	1818	3581	2525
Mankota	392	526*	4339	2919	1689	3378	2434
Tetraploids							
Tetracan	369	837	3790	1556*	1813	3047	1920*
Tetra-1 RWR	484	423*	4085	2199	1421	2753*	2118*
BozXTet	574	820	4058	1957*	1814	3316	2268*
LSD (0.05)	ns	504	ns	630	ns	683	315
Test Mean	1006	1844	6888	2999	1382	2790	3077
Test High	2400	5209	10904	5466	2317	3768	7245
Test Low	13	423	2590	729	627	207	307
No. Entries	91	91	86	88	88	82	98

* Entries significantly less than Bozoisky-II (P<0.05)

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Antonio J. Palazzo, Susan E. Hardy, Timothy J. Cary,
Kevin Jensen, Blair Waldron, and Steven Larson

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14. ABSTRACT
Our objectives were to demonstrate and make available new plant germplasms that are more beneficial for military training lands and to develop methods to better establish native plants that are competitive with invasive introduced plants. Under Strategic Environmental Research and Development Program (SERDP) project SI-1103, we developed germplasms that establish readily, stand up to wear from military vehicles, and compete well with invasive plants but are not themselves invasive. Validation and release of the new germplasms were accomplished under both the SERDP and Environmental Security Technology Certification Program (ESTCP) programs; under ESTCP we also initiated seed contracts and prepared a planting guide (Palazzo et al. 2009). Our ten releases (including six cultivars) are summarized in notices published in *Crop Science* or the *Journal of Plant Registrations*. One additional release is expected in the next year or two. Three germplasms were put into production, and the seed was made available for two years to land managers at eight Department of Defense (DoD) facilities. A commercial sale of 'FirstStrike' slender wheatgrass has been completed. We also developed seeding methods that have proven successful on eastern and western ranges to establish viable native plant stands quickly and compete with invasive plant establishment.

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